W. B. No. 840

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

MONTHLY WEATHER REVIEW

SUPPLEMENT No. 24

WEST INDIAN HURRICANES AND OTHER TROPICAL CYCLONES OF THE NORTH ATLANTIC OCEAN

By Charles L. Mitchell, Meteorologist

Submitted for publication July, 1924

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

SUPPLEMENTS TO THE MONTHLY WEATHER REVIEW

During the summer of 1913 the issue of the system of publications of the Department of Agriculture was changed and simplified so as to eliminate numerous independent series of bureau bulletins. In accordance with this plan, among other changes, the series of quarto bulletins—lettered from A to Z—and the octavo bulletins—numbered from 1 to 44—formerly issued by the U. S. Weather Bureau have come to their close.

Contributions to meteorology such as would have formed bulletins are authorized to appear hereafter as Supplements of the MONTHLY WEATHER REVIEW. (Memorandum from the Office of the Assistant Secretary, May 18, 1914.)

These Supplements comprise those more voluminous studies which appear to form permanent contributions to the science of meteorology and of weather forecasting, as well as important communications relating to the other activities of the U. S. Weather Bureau. They appear at irregular intervals as occasion may demand, and contain approximately 100 pages of text, charts, and other illustrations.

Owing to necessary economies in printing, and for other reasons, the edition of SUPPLEMENTS is much smaller than that of the MONTHLY WEATHER REVIEW. SUPPLEMENTS will be sent free of charge to cooperating meteorological services and institutions and to individuals and organizations cooperating with the Bureau in the researches which form the subject of the respective supplements. Additional copies of this SUPPLEMENT may be obtained from the Superintendent of Documents, Washington, D. C., to whom remittances should be made.

The price of this Supplement is 25 cents.

TABLE OF CONTENTS

LIST OF TABLES .

ILLUSTRATIONS

WEST INDIAN HURRICANES AND OTHER TROPICAL CYCLONES OF THE NORTH ATLANTIC OCEAN

PREFACE

This general study of the tropical storms of the North Atlantic Ocean was prompted by the results of a more restricted investigation—namely, an examination by the author of the idea, long held by him, that West Indian hurricanes *never* originate over the eastern two-thirds, approximately, of the Caribbean Sea. To test this idea all storms since 1886 which are shown in various publications as originating in the questioned area were listed, and their tracks replotted according to the daily maps of the Weather Bureau, (including reports from stations in the West Indies), the daily North Atlantic charts (prepared by the Hydrographic Office of the Navy until 1904 and since that time by the Weather Bureau), and all other available pertinent data, many of which were used apparently for the first time. *In every instance* the first evidence of storm development, although rather obscure in some cases, was found either over the western third of the Caribbean Sea (west of longitude 78° W.) or to the east of the eastern limits of the Caribbean Sea.

The results of this investigation proved so interesting and informative that the more comprehensive work of replotting the tracks of all tropical storms that originated over the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico during the entire period for which daily charts of the North Atlantic Ocean are available, 1887 to date, was undertaken. Not only were all previously published tracks for this period replotted, but also many storms were found whose tracks have not been charted heretofore. In extending the tracks of such of the tropical storms as crossed the Atlantic Ocean after recurving the following publications were found quite helpful: Deutsche Seewarte, Internationaler Dekadenbericht, and Tagliche Synoptische Wetterkarten für den Nordatlantischen Ozean von dem Danischen Meteorologisher Institut und der Deutschen Seewarte.

Acknowledgment is hereby made of helpful suggestions from the following officials of the Weather Bureau at Washington, D. C.: Mr. E. H. Bowie, Mr. W. P. Day, Dr. W. J. Humphreys, Mr. F. G. Tingley, and Mr. R. H. Weightman.

WEST INDIAN HURRICANES AND OTHER TROPICAL CYCLONES OF THE NORTH ATLANTIC OCEAN

INTRODUCTION

Tropical cyclones originate over the oceans both north and south of the Equator, except over the South Atlantic. North of the Equator they usually move at first in a westerly or northwesterly direction, later recurving, as a rule, to the northeast. Those that develop south of the Equator usually move at first in a westerly or a southwesterly direction, later recurving, as rule, to the southeast.

The typhoons of the western Pacific Ocean, the cyclones of the Indian Ocean and the Bay of Bengal, and the hurricanes of the South Pacific Ocean, the eastern North Pacific Ocean, and the North Atlantic Ocean (including the Caribbean Sea and the Gulf of Mexico) are essentially the same in character. This study is confined to the hurricanes and less intense tropical storms that have originated since 1886 over the Atlantic Ocean (usually between 9° and 20° north latitude) the Caribbean Sea, or the Gulf of Mexico.

A more or less complete list of hurricanes in the West Indies from 1493 to 1855 was published by Pöey.[1] From 1856 to 1877 the occurrence of 12 hurricanes was noted by various writers. The hurricanes of 1878 to 1900, inclusive, were traced and discussed by Garriott,[2] and Fassig[3] issued a comprehensive bulletin covering the period from 1876 to 1911, inclusive. In addition, Viñes[4] fully covered the hurricanes that directly affected the island of Cuba.

TRACKS OF TROPICAL CYCLONES OF THE NORTH ATLANTIC OCEAN

The storms for each of the so-called hurricane months, June to November, during the years 1887 to 1923, inclusive, are charted separately as Figures 1 to 8. The September and October tracks, on account of their great number, are divided, those for the first 15 days of the month appearing on one figure and those for the remainder of the month on another. In addition, the paths of three storms that occurred in May and December were charted, but the chart has not been reproduced. Each storm is assigned to the month in which it originated, irrespective of the date on which it reached land or became severe, if at all. The storms are classified in accordance with their intensity while south of latitudes 30° to 35° N., and are divided into three groups, as follows:

1. Storms of known hurricane intensity (with winds of at least 60 miles an hour reported).
2. Storms whose intensity is in doubt, because of an insufficient number of reports.
3. Storms known to be of less than hurricane intensity.

Comparison of the storm tracks from month to month shows strikingly the advance and decline of the hurricane season.

June (*fig. 1*).—Practically all tropical disturbances in the regions here studied originate either over the Caribbean Sea west of longitude 80° W. or over the Gulf of Mexico, and comparatively few are of hurricane strength. Every June storm that has developed over the western Caribbean Sea has moved for several days in a northwesterly or a north-northwesterly direction before recurving. Of the 16 June storms charted, 9 dissipated before reaching latitude 37° N. and 2 others before reaching latitude 45° N., while the remaining 5 maintained their identity for a much longer time. One of these reached the coast of Norway before dissipating, and another disappeared north of Iceland.

July (*fig. 2*).—In this month there was only one more storm than in June, but the probability of a tropical disturbance developing hurricane strength is then much greater. Only 2 of the 17 July storms developed over the western Caribbean Sea and only 3 over the Gulf of Mexico. One of the remaining July storms developed in the vicinity of the Bahama Islands, 3 some distance to the eastward, while all the other entered the Caribbean Sea from the east. As in June, the length of the tracks of the majority of the storms is comparatively short. Of the 17 storms charted, 11 dissipated before reaching latitude 37° N. and one other before reaching latitude 45° N., while the remaining 5 were traced for much greater distances, 2 of them disappearing in the region southwest of Greenland.

August (*fig. 3*).—In this month a marked increase was found both in the number of tropical storms and in the percentage of the total number that developed hurricane intensity. The place of origin was found, in many instances, far to the eastward. None has originated over the Caribbean Sea and very few over the Gulf of Mexico during the past 37 years. Many of the August storms originated in the vicinity of the Cape Verde Islands. Some of these moved westward, entering the Caribbean Sea and passing south of the islands of Haiti and Cuba; others turned more to the northwest before reaching the Lesser Antilles and passed north of Haiti and Cuba. The remainder moved northwestward, recurving in about latitudes 25° to 30° N. and between longitudes 50° and 70° W. All August storms that passed south of Haiti reached Central America or the west Gulf coast without recurving, and all except 2 in this class dissipated without recurving soon after reaching land. One of these two exceptions is the great Galveston hurricane of 1900, which is classified as an August storm, although it did not reach Galveston until September 8. It originated far to the eastward of the Lesser Antilles before the end of August. Of the storms that passed north of Haiti in August a few reached the middle Gulf coast before recurving, but the great majority of them recurved east of Florida. The August storms that recurve usually travel far. No less than 14 of the 39 charted were traced at least as far east as the longitude of Iceland and several much farther.

The height of the hurricane season is reached during August and the first part of September. Over 54 per

[1] Andreas Pöey: Table chronologique de quatre cents cyclones. Paul Dupont, Paris, 1862, 8vo., pp. 40.
[2] E. B. Garriott: West Indian Hurricanes. Bulletin H, U. S. Weather Bureau, 1900, 4to., pp. 69, plates 7.
[3] O. L. Fassig: Hurricanes of the West Indies. Bulletin X, U. S. Weather Bureau, 1913, 4to., pp. 28, plates 25.
[4] B. Viñes: Cyclonic Circulation and the Translatory Movements of West Indian Hurricanes, U. S. Weather Bureau, Publication No. 168, 1898, 8vo., pp. 34.

cent of the true hurricanes of the past 37 years developed within this period of approximately 6 weeks. In August, 1893, there were four hurricanes in progress at the same time, and in September, 1900, there were three, including the Galveston hurricane of that year. (See figs. 66 and 66a.)

September, first half (*fig. 4*).—During this time tropical storms, as a rule, move northwestward rather than west-northwestward before recurving. However, some do not recurve at all, but are deflected to the westward by anticyclones to the northward and reach the west Gulf coast. The great hurricane of September, 1919, is one of this class. Before the middle of September disturbances again develop occasionally over the western third of the Carribbean Sea, and there is an increase in the number that develop over the Gulf of Mexico.

While all tropical storms in the Northern Hemisphere apparently seek to move northward at the first favorable opportunity, this tendency is especially noticeable in the paths of the West Indian hurricanes that develop during the first half of September. (See fig. 4.) Out of a total of 46 of these storms, 15, or almost one-third, passed northward or northeastward in the vicinity of or to the east of Bermuda. As this study of tropical storms progressed, it became more and more apparent that *any tropical storm will recurve into a trough of relatively low pressure that may exist when the tropical storm arrives in the same region, irrespective of the longitude or the time of the year.* The fact that the great majority of the West Indian hurricanes during the early part of the storm season recurve farther to the west is due solely to the infrequency then of troughs of low pressure east of the Atlantic Coast States of the southeastern United States. The so-called permanent area of high pressure that at this season normally extends from the region of the Azores west-southwestward to the coast of the United States seldom breaks down. This being true, it is clear that no storm will "break through" and recurve until it reaches a region where south or southwest winds prevail aloft and relatively low pressure to the northward is shown on the weather map. However, as autumn approaches, storm activity in extratropical regions increases and the breaking down of the Atlantic high pressure area occurs more often, so that the chance of a westward-moving tropical storm encountering one of these areas of diminishing pressure with south or southwest winds aloft is materially increased. If as large a number of storms should develop east of the Lesser Antilles after the middle of September as before that time, it seems certain that a larger percentage of them would recurve east of the longitude of Bermuda because of the continued increase in storm activity in extratropical regions and the consequent increase in the number of troughs of low pressure into which the tropical storms might move.

September, last half (*fig. 5*).—During the latter half of September there is a decided decrease both in the number of tropical storms in the regions under consideration and in the percentage of storms of hurricane strength. While the total number of storms is much smaller than for the first half of the month, there is a marked increase in the number that develop over the western third of the Caribbean Sea. These usually move to the middle or east Gulf coast. Moreover, no storms of hurricane intensity, irrespective of place of origin, reached the Texas or western Louisiana coasts after the middle of September during the period 1887 to 1923, inclusive, with the exception of the hurricanes of September 11–21, 1887, and October 12–17, 1912, both of which moved inland a short distance north of Brownsville, Tex. Only one hurricane that developed during the latter half of September was traced back to the vicinity of the Cape Verde Islands; however, it is quite likely that others, first noted between longitudes 50° and 60° W. originated near those islands; but lack of vessel reports at the time made it impossible to extend their tracks farther to the east.

A large percentage of all September storms of tropical origin reach high latitudes before dissipating. No less than 17 of those that occurred during the past 37 years reached at least 60° N. and 14 of these were traced beyond 65° north latitude.

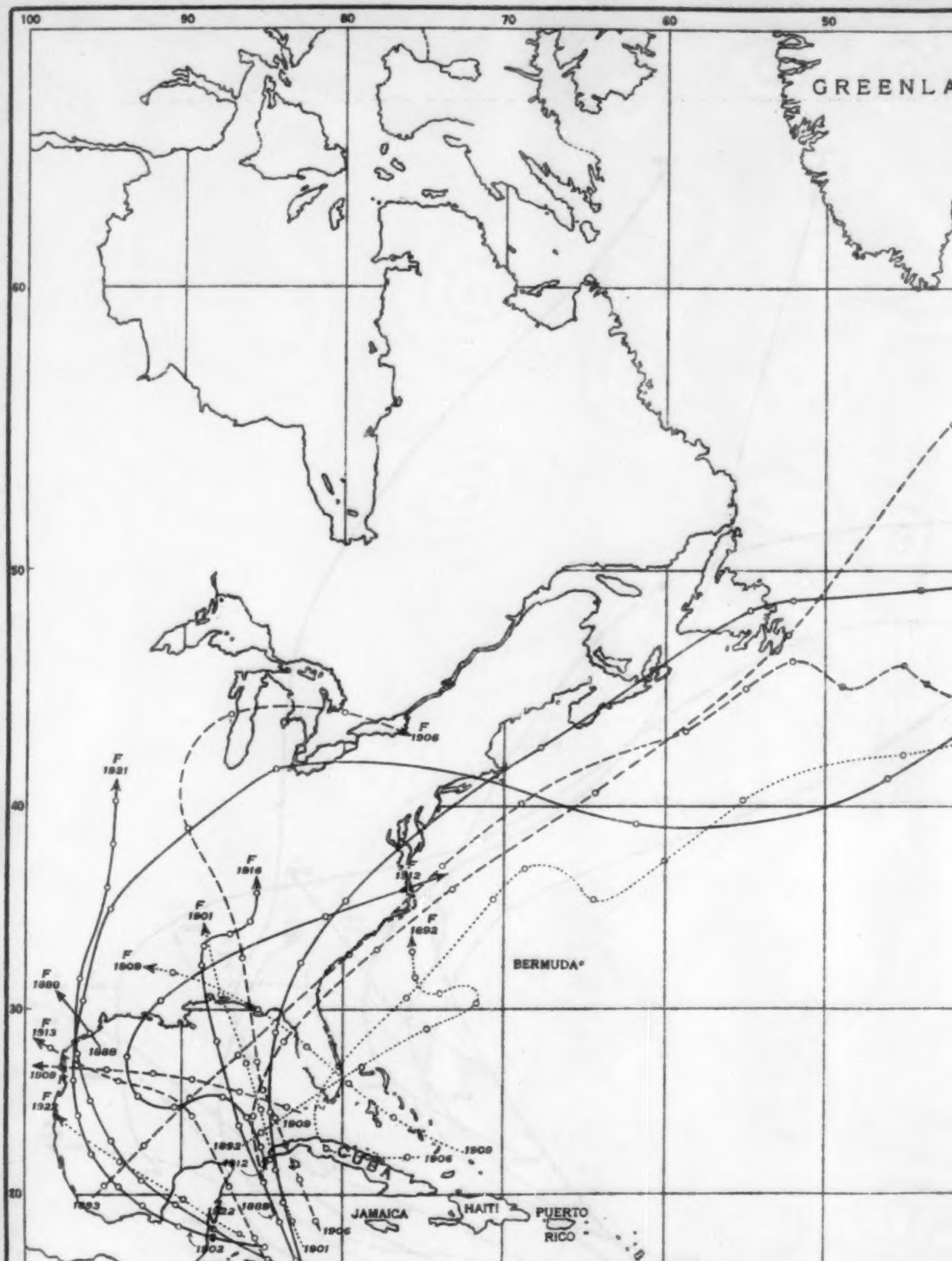
October, first half (*fig. 6*).—After noting the decided decrease in the number of tropical storms that attain hurricane strength during the latter half of September, it is rather surprising to find that there is another period of maximum frequency of these severe storms during the first half of October. This period shows a total of nearly twice as many as the latter half of September, more than five times as many as the latter half of October, and nearly two-thirds as many as the first half of September. No explanation of this anomalous distribution is offered.

Many of the early October tropical storms move in a north-northwesterly or west-northwesterly direction for several days before recurving. The paths of some appear quite erratic, due to the control exercised by areas of high pressure which at this season of the year are beginning to move across the United States with greater frequency and whose influence extends considerably farther south than in the summer season. The paths of three October storms described a loop (always to the left), notably that of the hurricane of October, 1910, that twice passed over the western end of Cuba. (See figs. 46–53.) Another October hurricane, that of 1922, was deflected to the southwest over the Bay of Campeche and into Mexico in the vicinity of Frontera. This is the only instance of the kind during the 37-year period. Again, as in the latter half of September, only one hurricane was traced back to the eastern Atlantic. That others were not found was due very likely to lack of vessel reports at the time in the region east of the Lesser Antilles.

October, last half (*fig. 7*).—After the middle of October the decline in the hurricane season sets in rapidly. Few of these tropical storms now develop hurricane intensity, and only on rare occasions do they enter the Gulf of Mexico. The hurricane of late October, 1921, that passed eastward over the Florida peninsula north of Tampa was a notable exception. No other true hurricane that developed after October 15 has entered the Gulf of Mexico during the past 37 years, although a very few that developed previous to the 15th entered the Gulf shortly after that date. None of the late October storms were traced back to the vicinity of the Cape Verde Islands, but there is a possibility that a few of them originated in that region. As in September, a large percentage of these tropical storms that develop during October do not dissipate before reaching high latitudes. Of the 71 charted there were 20 that moved as far north as 60°, and 10 of these passed beyond 65° north latitude.

November (*fig. 8*).—The November storms here considered are few in number, and some of them are apparently nothing more than disturbances that develop in the southern end of troughs of low pressure moving eastward over the United States and extending much farther south than during the warmer months. The disturbances that develop in this manner move northward or northeastward from the time of their inception. Only two storms of known hurricane intensity have occurred in November

Fig. 1. Tracks of Tropical



ropical Cyclones of North Atlantic, June

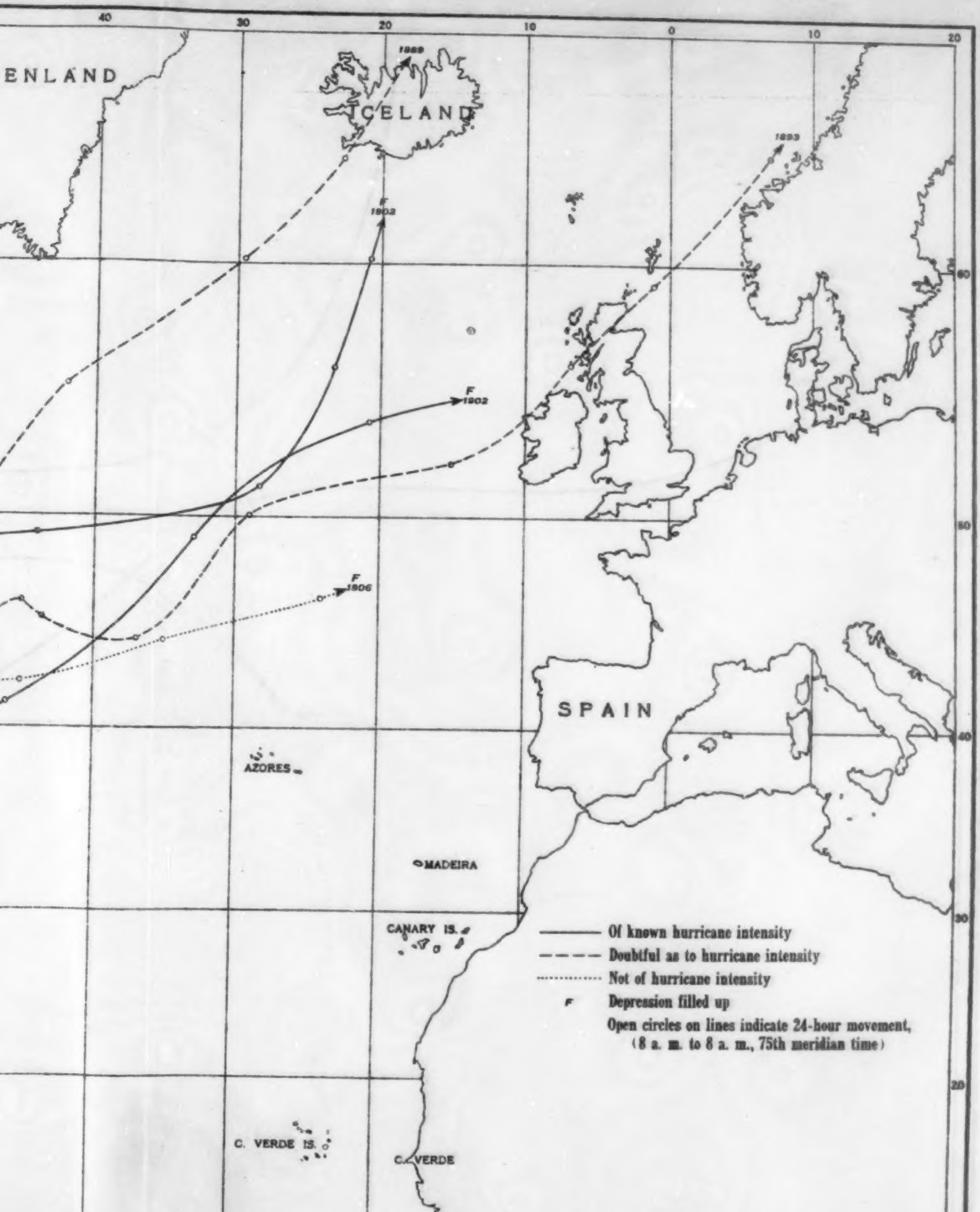
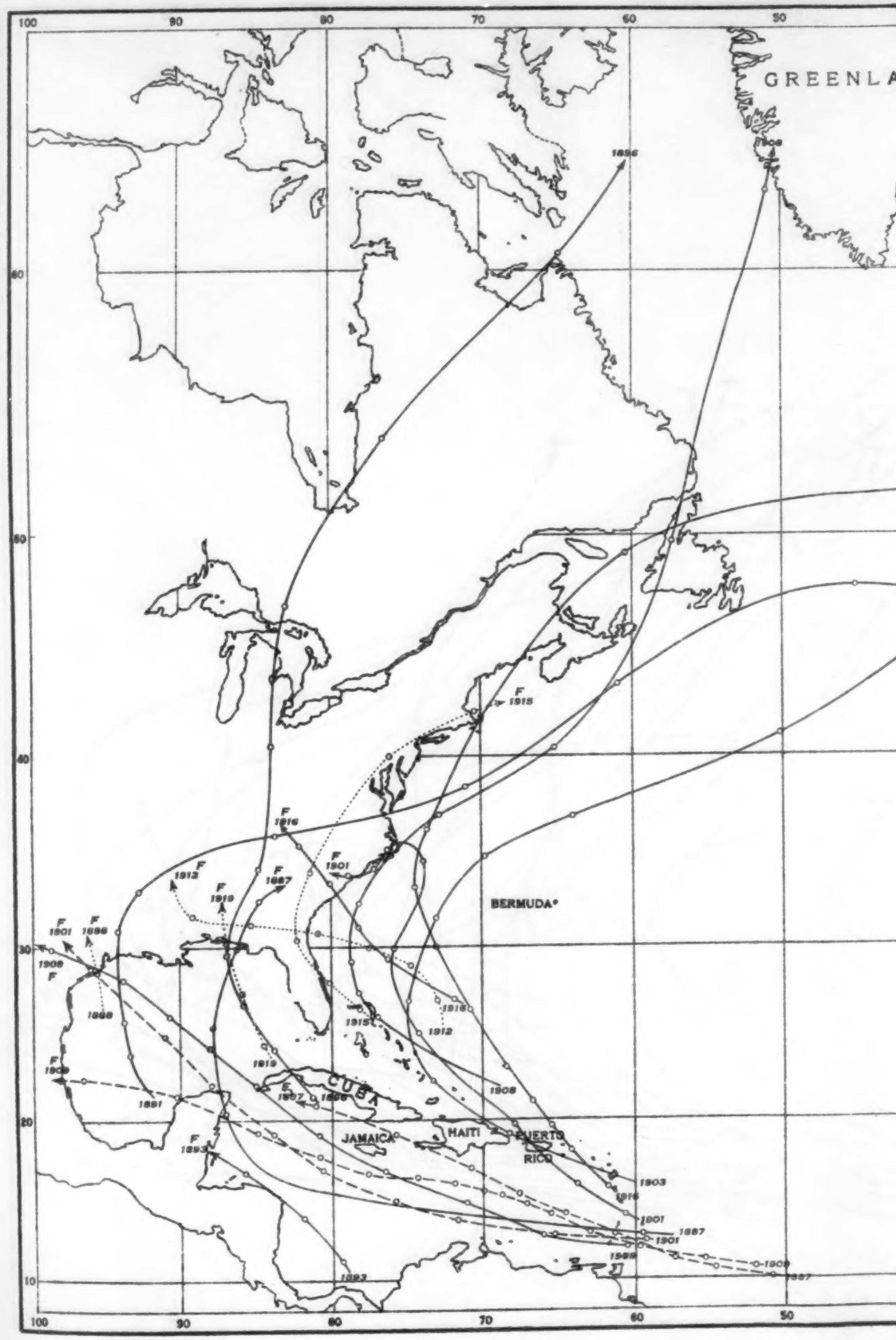


Fig. 2. Tracks of Tropical C



ropical Cyclones of North Atlantic, July

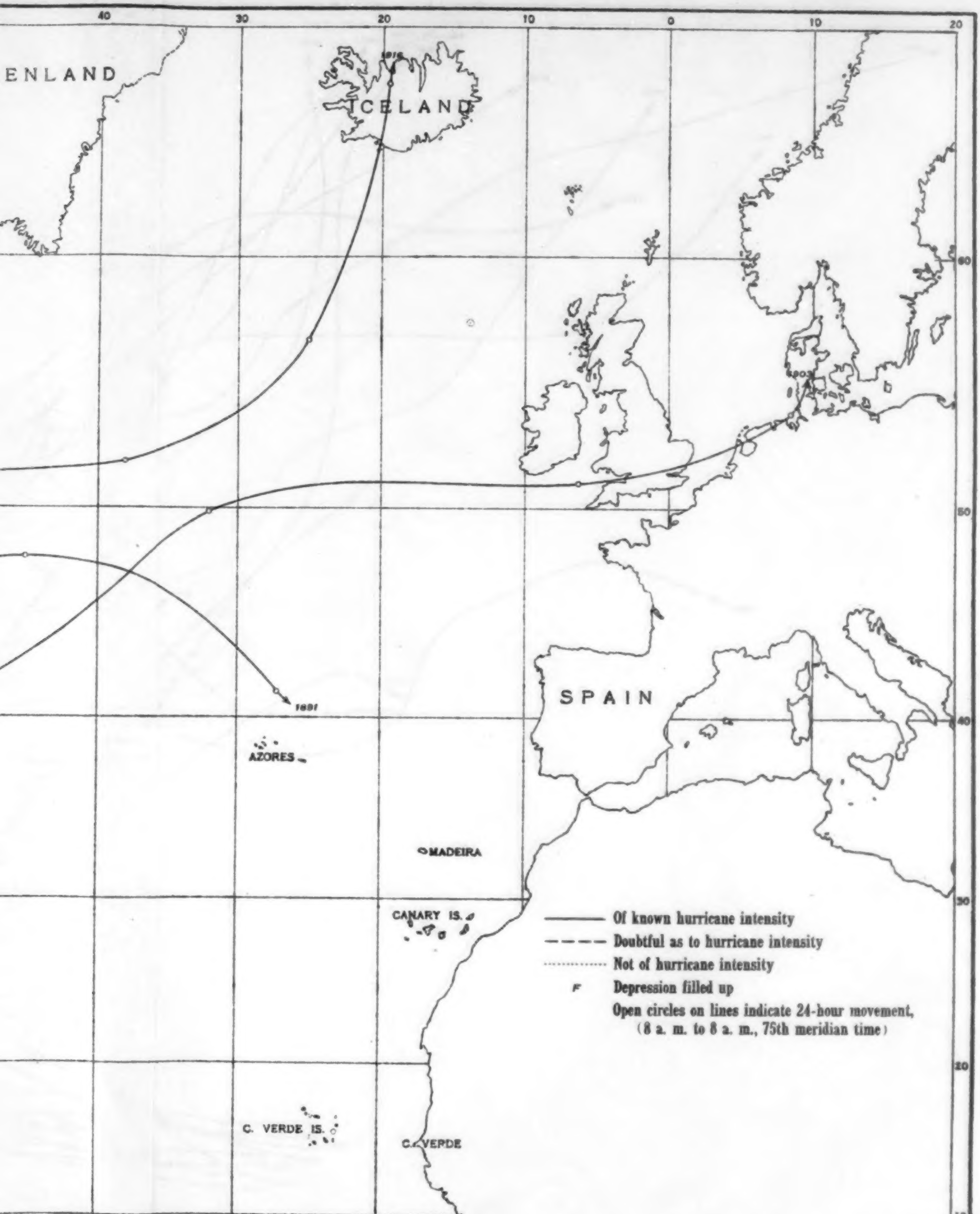
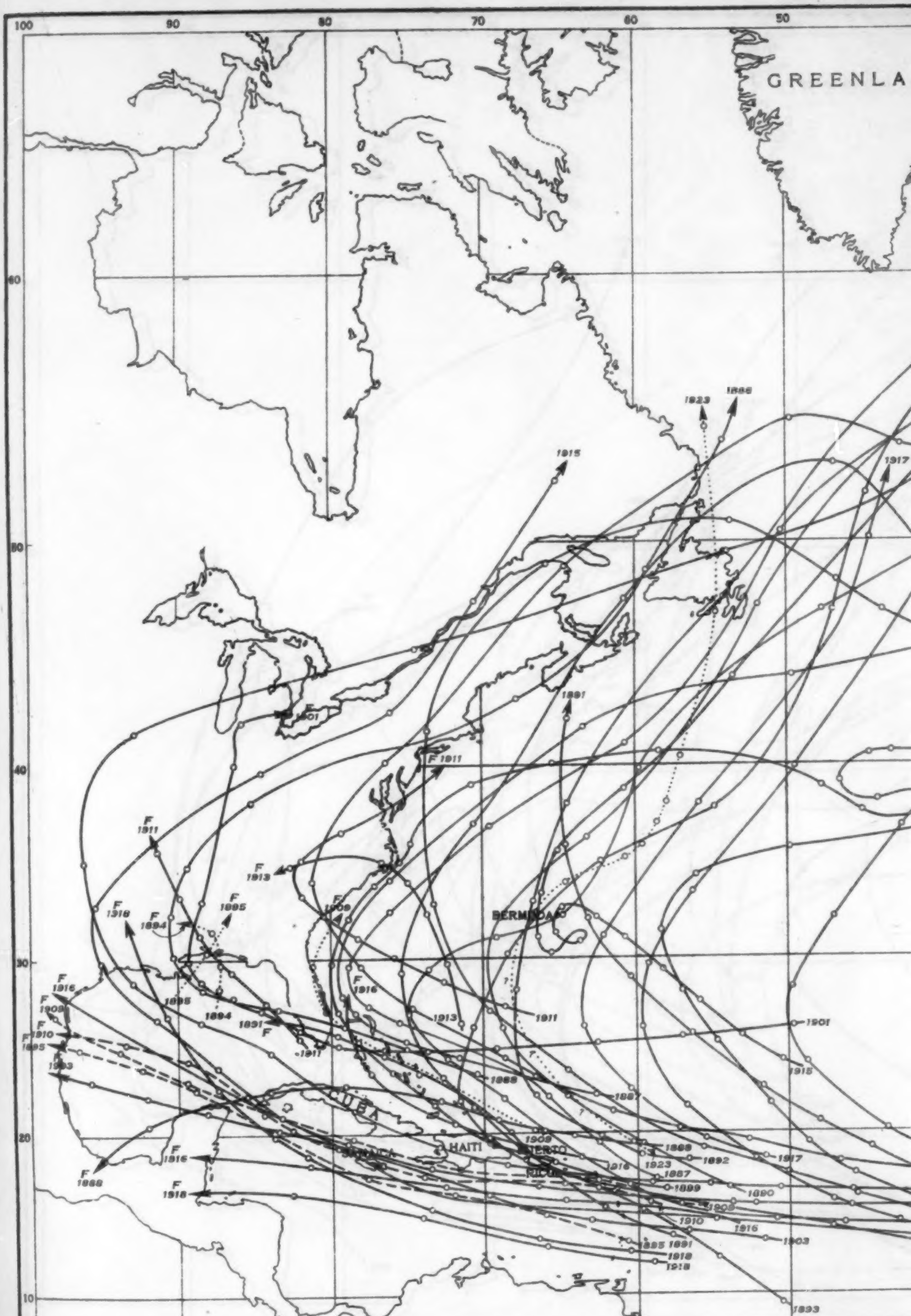


Fig. 3. Tracks of Tropical Cyclone



Cyclones of North Atlantic, August

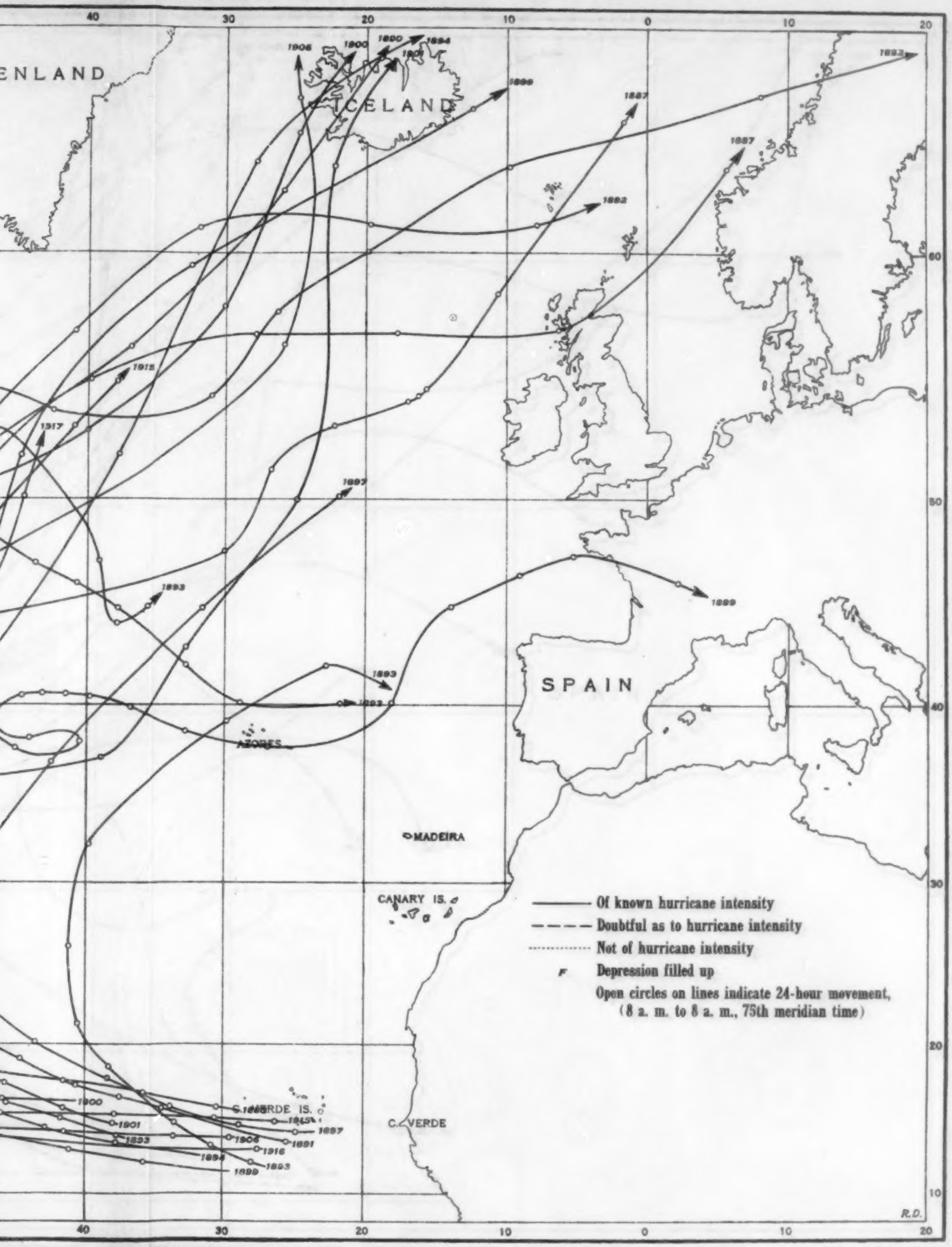
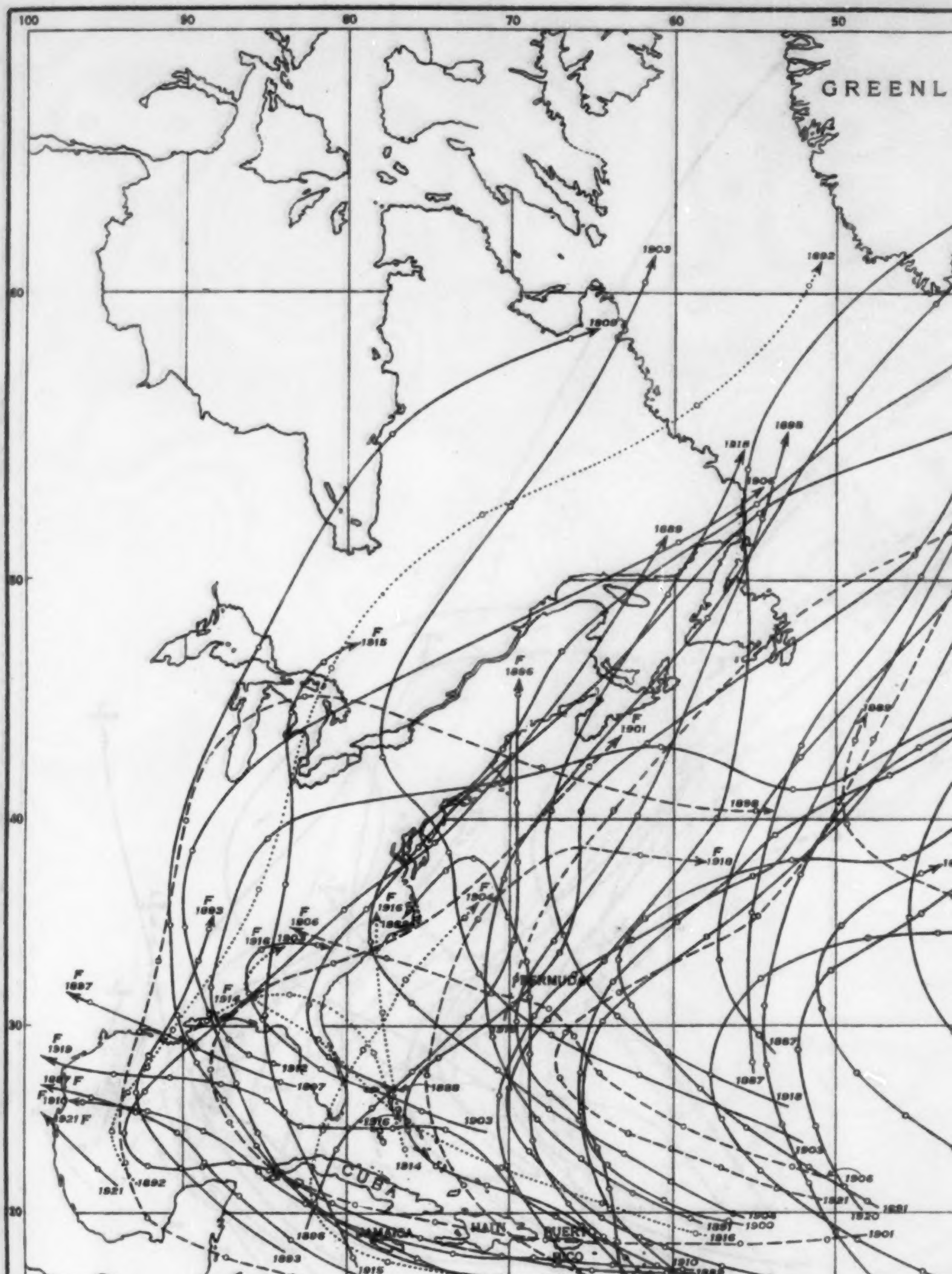


Fig. 4. Tracks of Tropical Cycl



cal Cyclones of North Atlantic, September 1-15

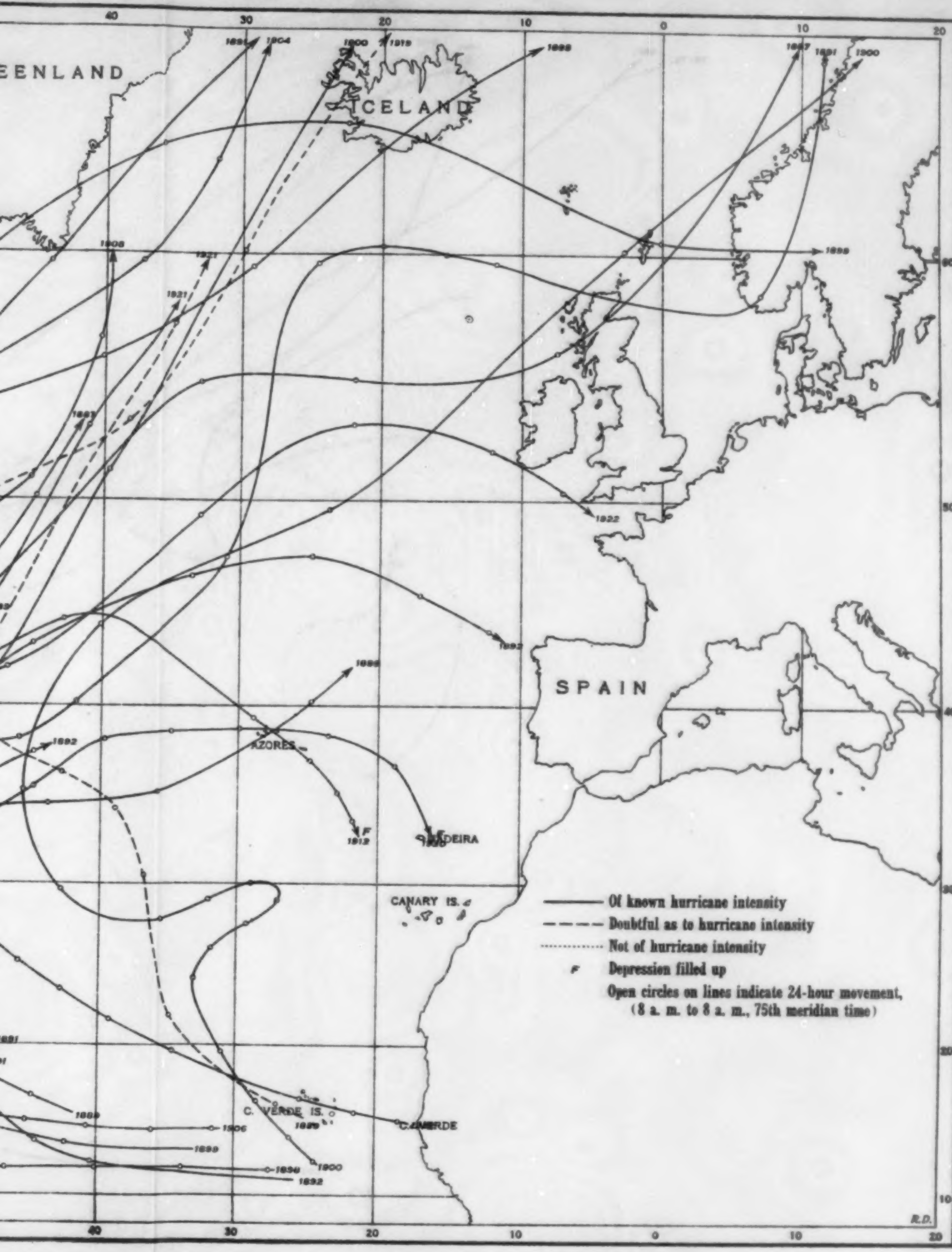
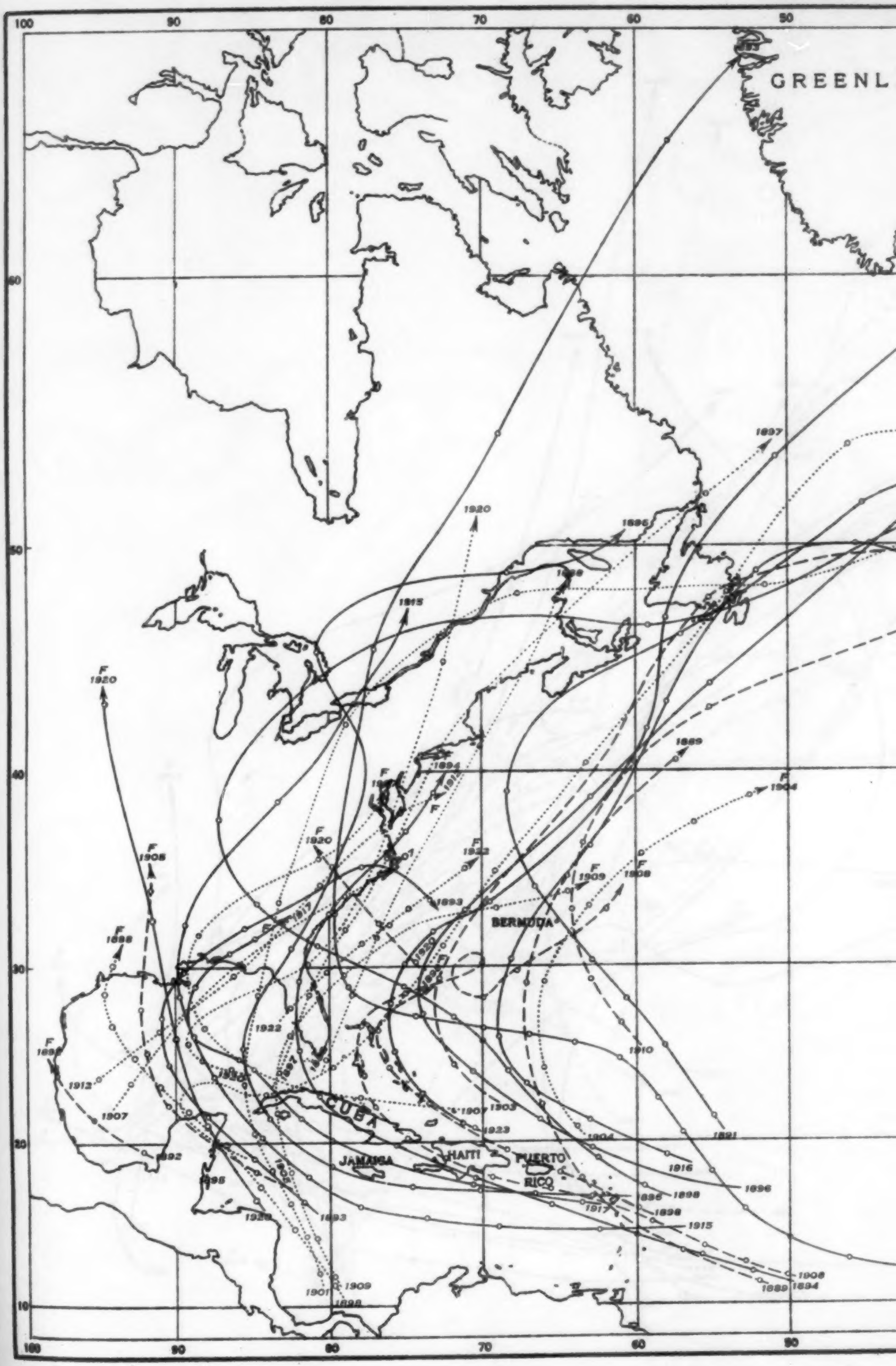


Fig. 5. Tracks of Tropical Cyclo



al Cyclones of North Atlantic, September 16-30

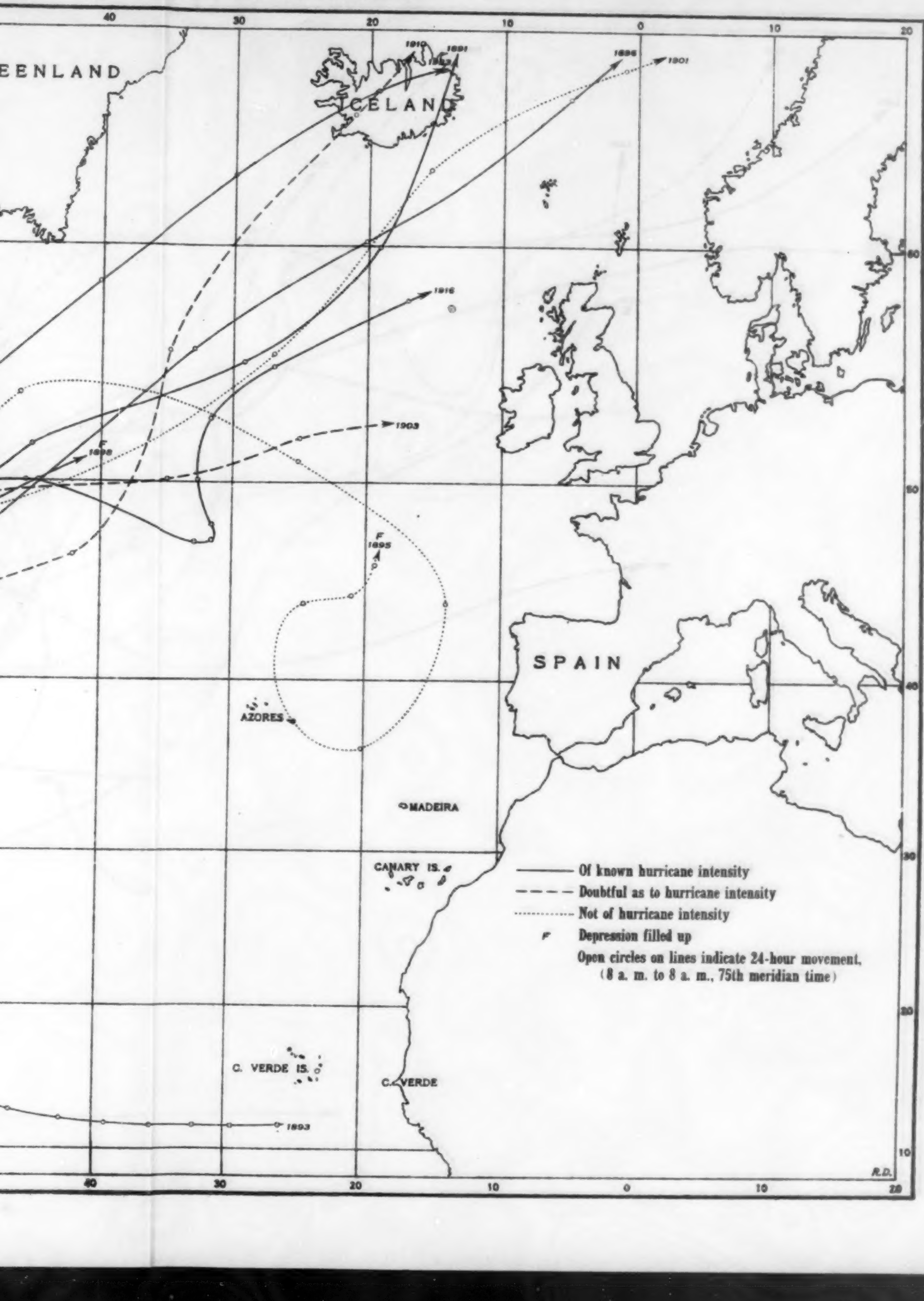
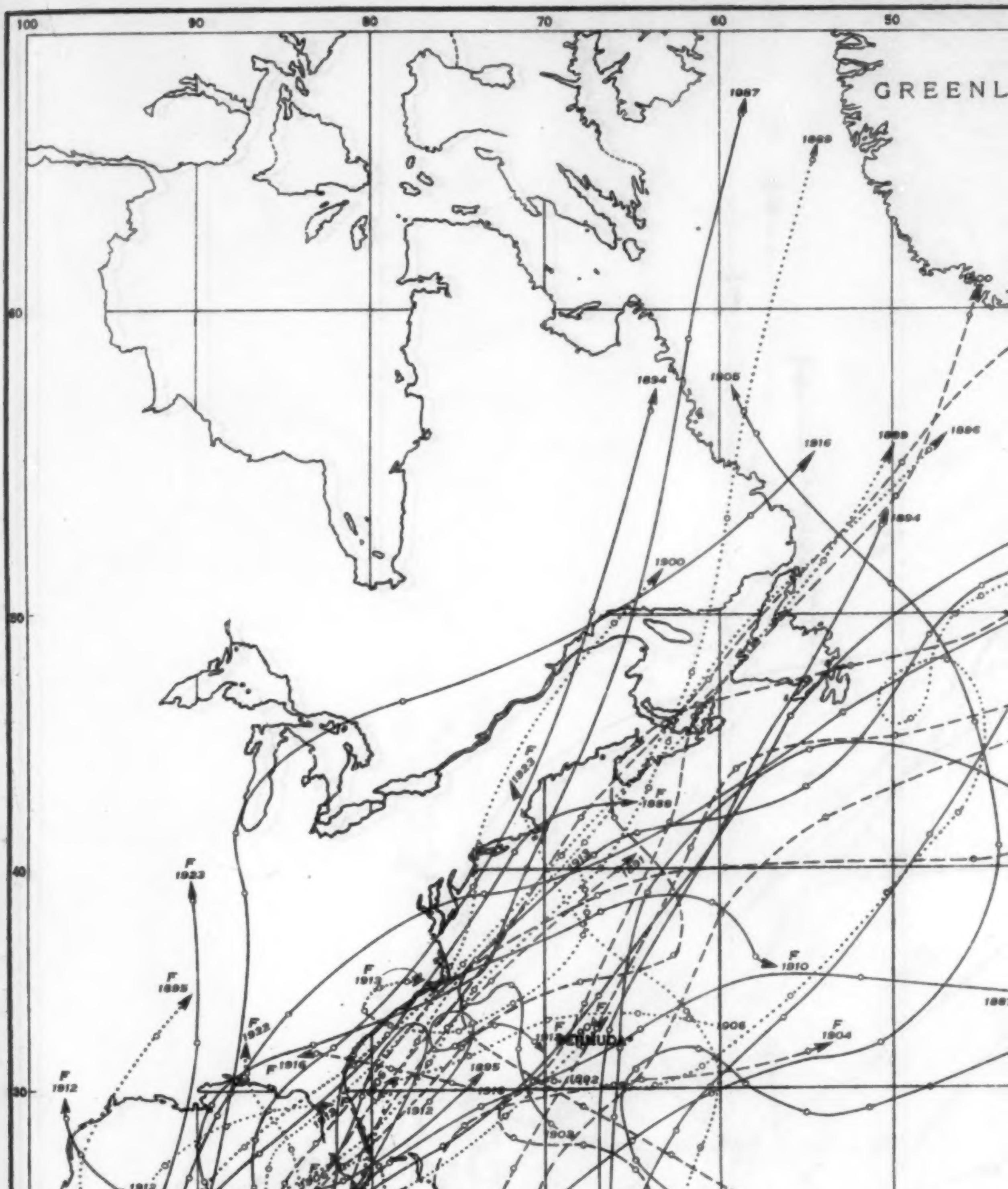


Fig. 6. Tracks of Tropical Cyc



cal Cyclones of North Atlantic, October 1-15

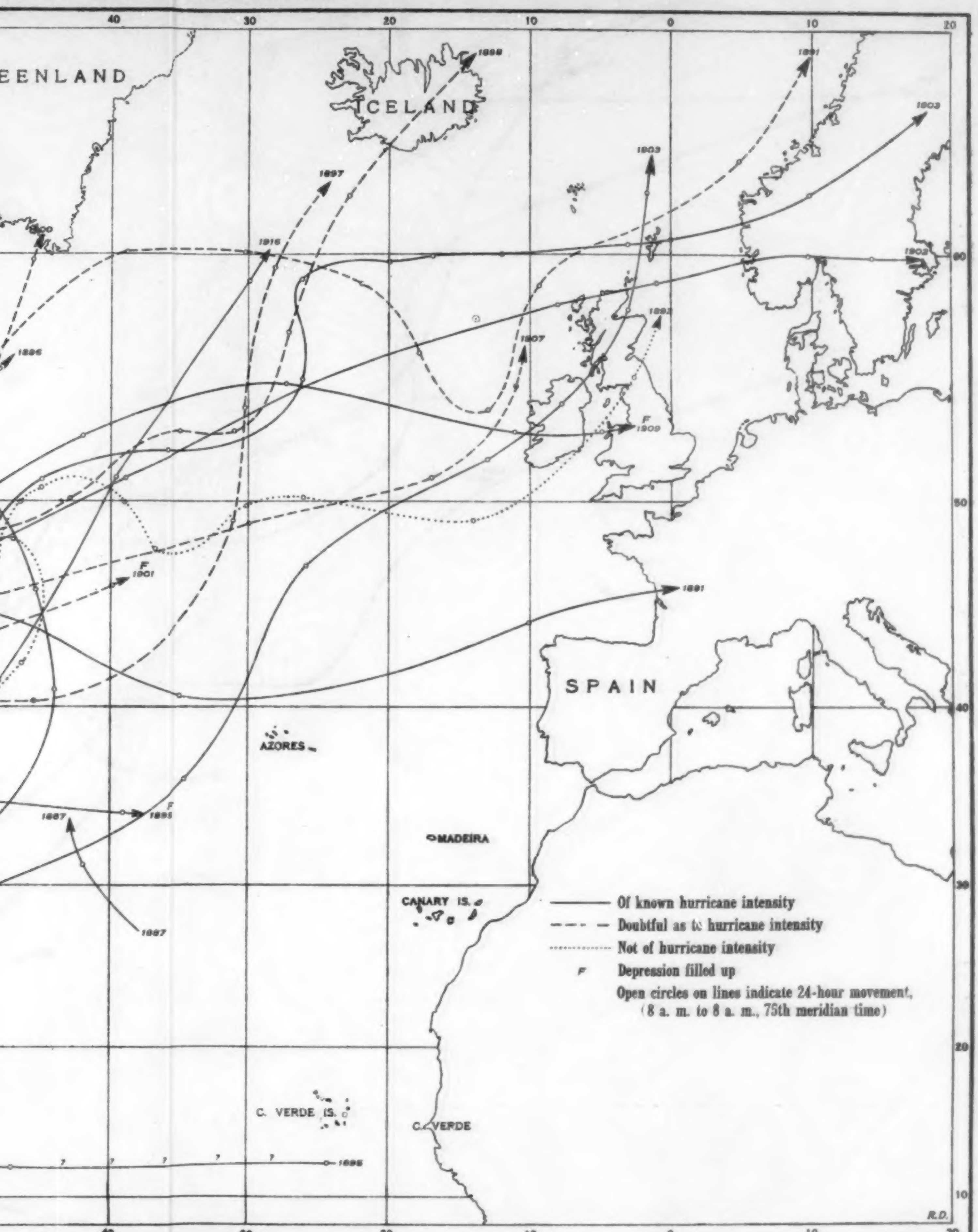
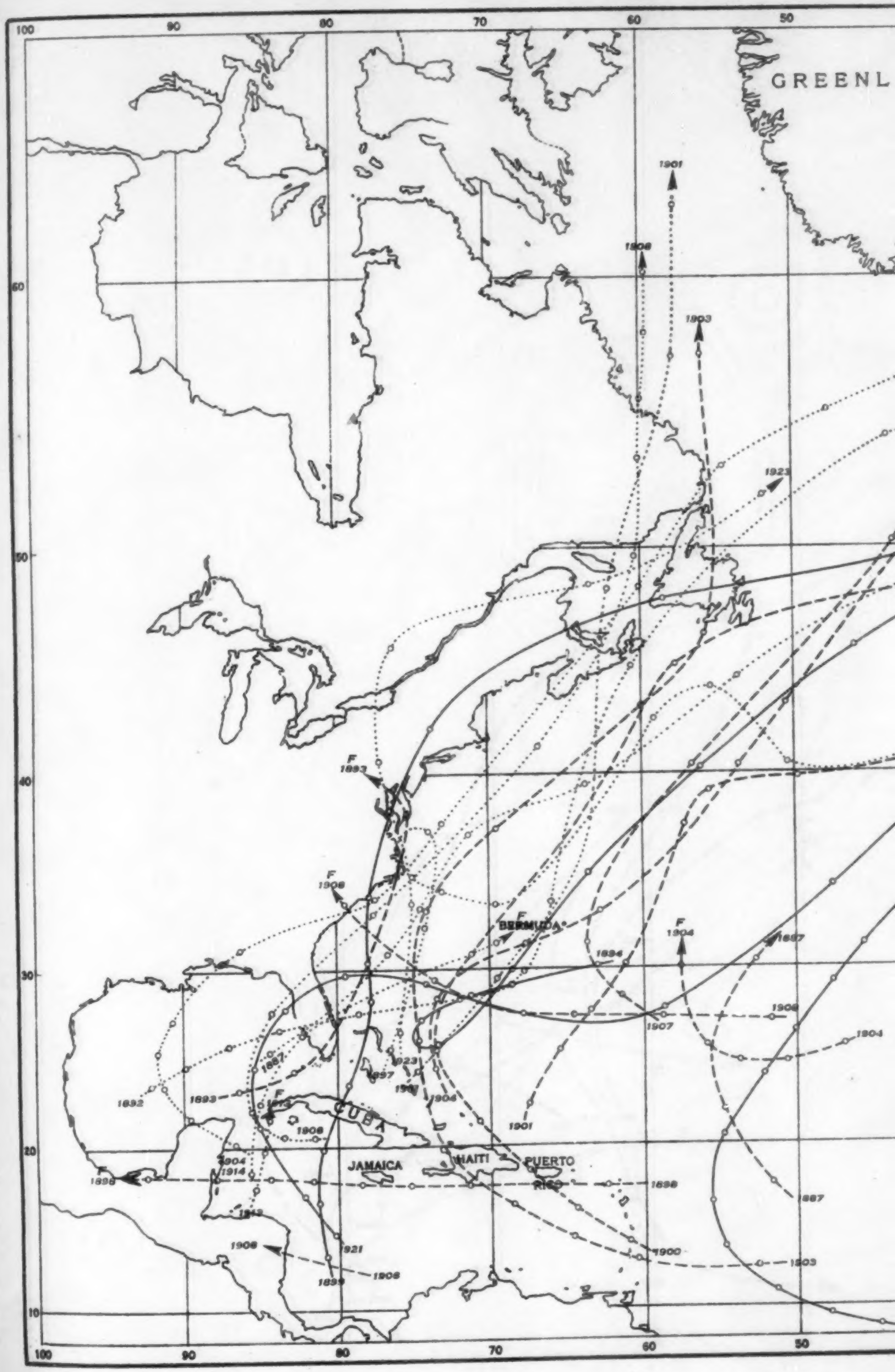


Fig. 7. Tracks of Tropical Cy



...pical Cyclones of North Atlantic, October 16–31

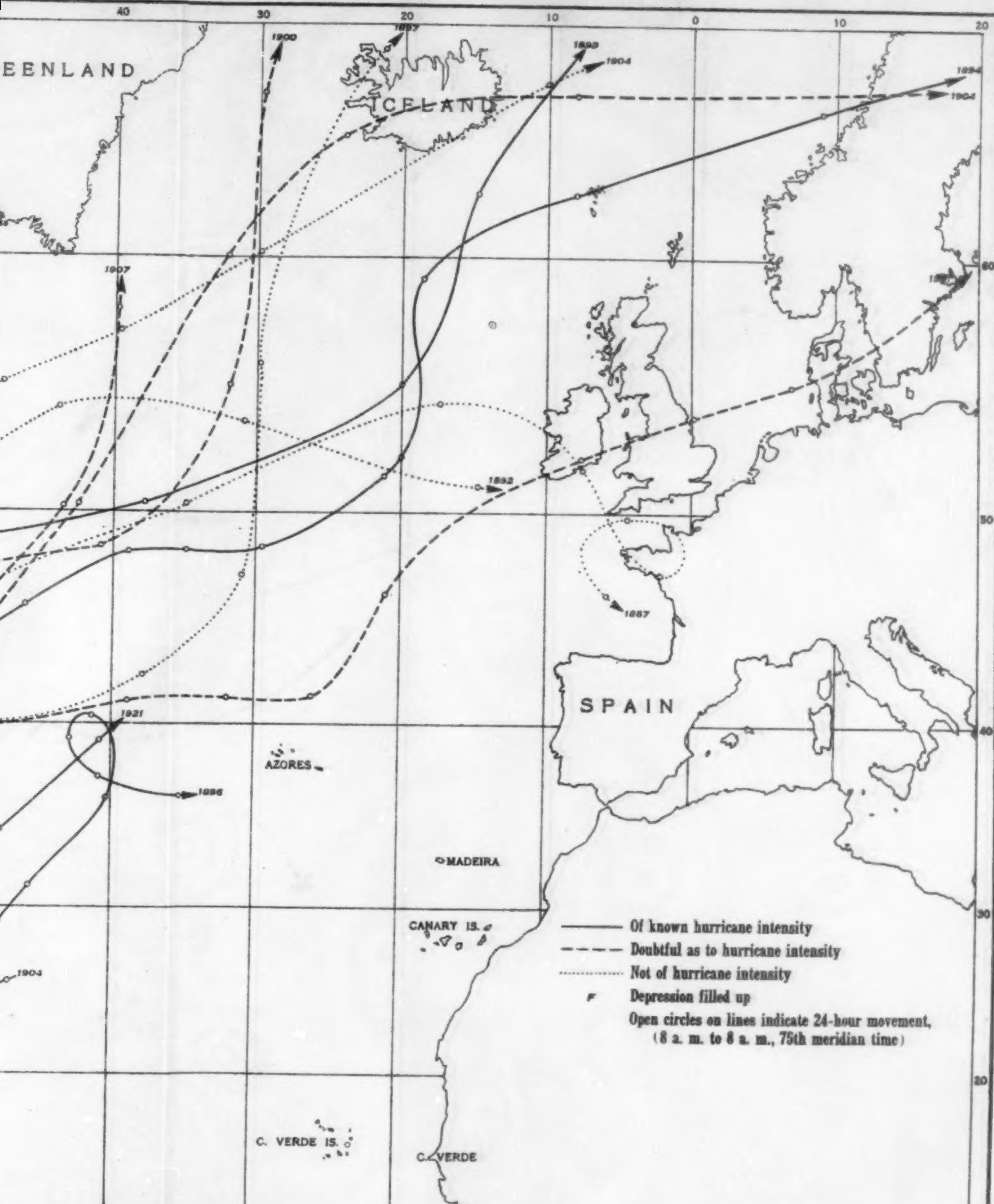
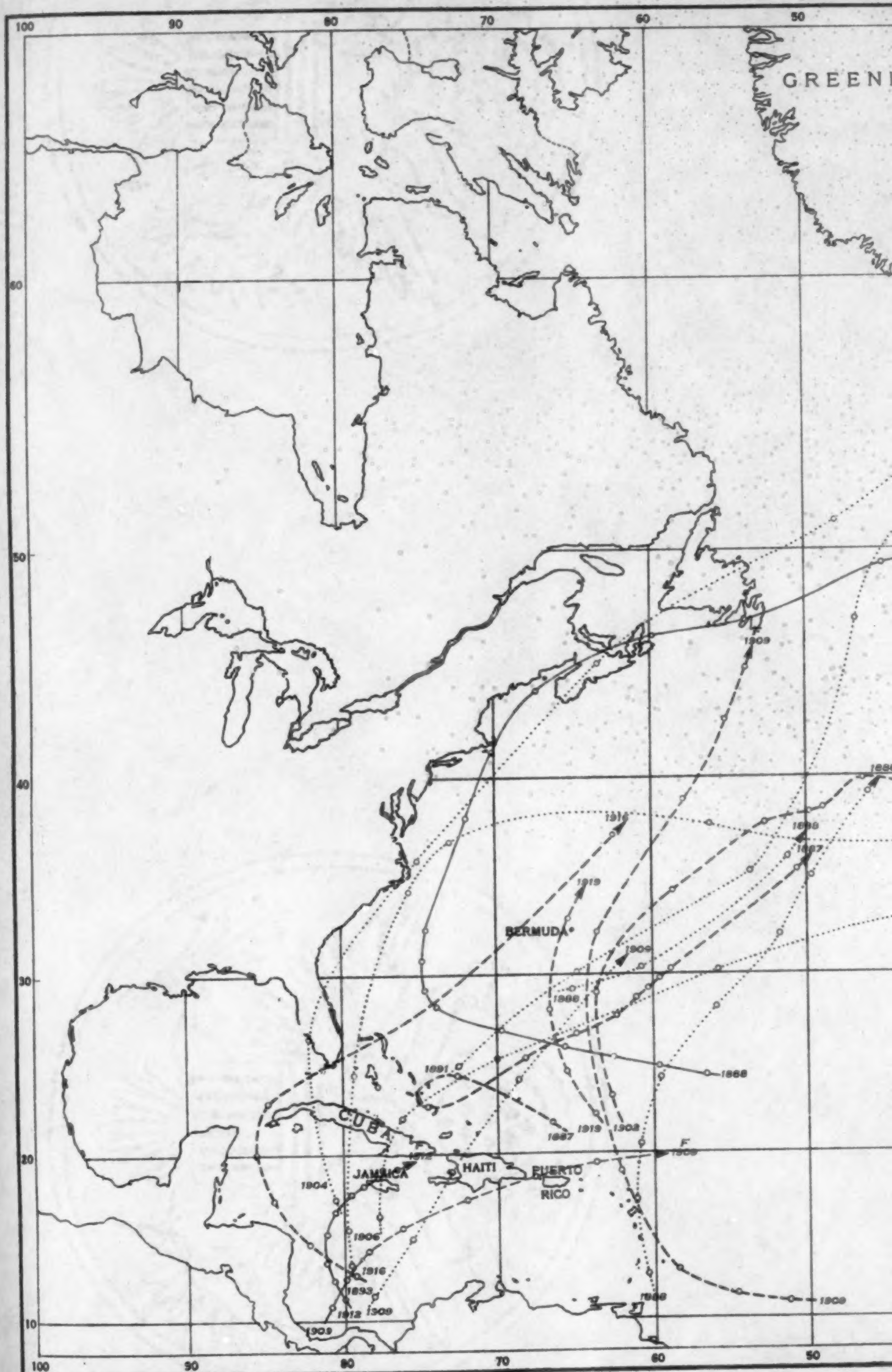
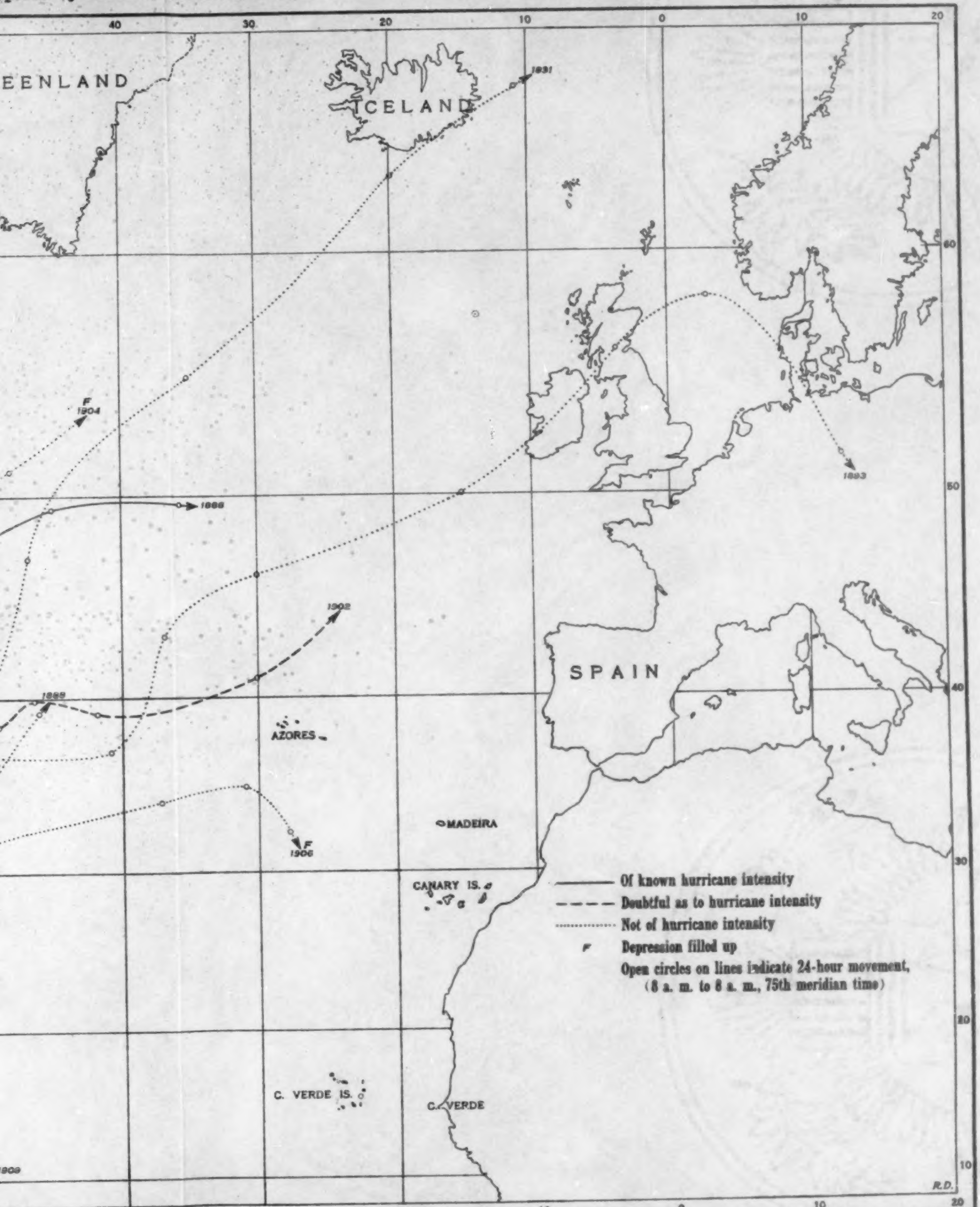


Fig. 8. Tracks of Tropical C



...opical Cyclones of North Atlantic, November



since 1886; one of these was the exceptionally severe hurricane which passed very slowly over the western part of Jamaica in 1912. This storm is described in detail on a later page.

YEARLY FREQUENCY

The number of tropical storms of the North Atlantic Ocean for each year of the period 1887–1923 is shown in the subjoined table:

1887	16	1907	4
1888	10	1908	6
1889	8	1909	12
1890	1	1910	4
1891	11	1911	2
1892	9	1912	8
1893	11	1913	4
1894	6	1914	2
1895	6	1915	5
1896	6	1916	13
1897	5	1917	2
1898	7	1918	4
1899	5	1919	4
1900	6	1920	4
1901	10	1921	5
1902	4	1922	5
1903	8	1923	5
1904	9		
1905	3	Total	239
1906	9		

The above numbers are presented graphically in Figure 9.

Of the total of 234 tropical storms in the regions under consideration during the 36-year period ending with 1922, 138, or 59 per cent, occurred during the first 18 years, and 96, or only 41 per cent, during the second 18 years. For the whole period an average of 6½ storms occurred per year, but during the last 18 years this number was reached or exceeded only four times, and not at all since 1916. Grouped in periods of five years each (omitting 1922 and 1923) the numbers are as follows:

1887–1891	46	1907–1911	29
1892–1896	37	1912–1916	32
1897–1901	33	1917–1921	19
1902–1906	33		

The average number of storms for each five-year period did not vary materially from 1892 to 1916, inclusive, but there was a large excess during the five-year period 1887–1891 and as great a deficiency during the five-year period 1917–1921. Furthermore, only five tropical storms occurred during each of the years 1922 and 1923, so that the total number of these storms during the past seven years, 1917–1923, inclusive, would just equal the smallest number recorded during any previous five-year period since 1886.

Monthly frequency of West Indian hurricanes and other tropical storms of the North Atlantic Ocean (1887–1923)

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Season
Number of storms	1	16	17	39	78	71	15	2	239
Percentage	0	7	7	16	33	30	6	1	

	Storms of known hurricane intensity	Doubtful	Not of hurricane intensity	Total
May	0	0	1	1
June	6	5	5	16
July	10	3	4	17
August	32	3	4	39
September	46	15	17	78
October	26	23	22	71
November	2	6	7	15
December	0	2	0	2
Total	122	57	60	239
Percentage	51	24	25	

The months of September and October have been divided into halves and the results tabulated, as in the preceding table. Taking first the storms of known hurricane intensity, we find 34 during the first half of the month of September, falling to 12 during the last half, rising to 22 during the first part of October, and followed by a sudden decline to 2 storms during the last half. Of the disturbances which are doubtful as to hurricane intensity, 7 occurred during the first half of September, 8 during the last half, 12 during the first part of October, and 11 during the latter. Of the tropical disturbances not of hurricane intensity, September showed 5 for the first part and 12 for the last half, while October showed 13 and 9. The totals for the semimonthly periods were September, 46 and 32; October, 47 and 24.

The above figures show that 149, or 62 per cent, of the total of these 239 tropical storms recorded during the past 37 years occurred during the months of September and October, and 188, or 78 per cent, during the three months, August, September, and October. Further examination of the figures shows that when one of these tropical disturbances develops during June there are about 3½ chances in 9 that it will increase in intensity until it reaches hurricane strength; during July,

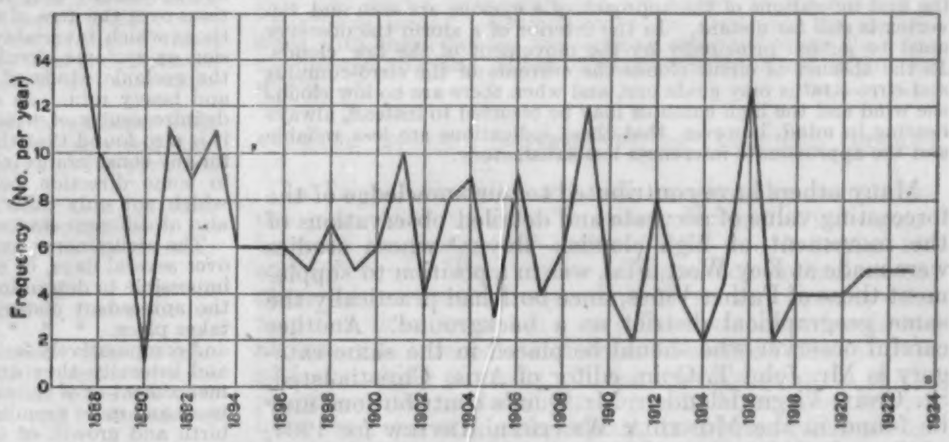


FIG. 9.—Hurricane frequency, 1887–1923

5 in 9; during August, 7½ in 9; during the first half of September, 6½ in 9; during the latter half of September, 3½ in 9; during the first half of October, 4 in 9; during the second half of October, 1½ in 9; and during November, 1 in 9.

PRECURSORY SIGNS OF TROPICAL CYCLONES

Accurate and detailed observations of the high clouds, especially cirrus (Ci.) and cirro-stratus (Ci.-St.), when made by an experienced observer may often be helpful in determining, first, the presence of a distant tropical cyclone, and second, its geographic position with reference to the observer. The late Rev. Benito Viñes, S. J., director Belen College Observatory, Habana, Cuba, was, among the first to study the connection between the movement of the high clouds, Ci. and Ci.-St., and the movement of tropical cyclones.

The results of Father Viñes' labors are summarized in a paper [5] contributed to the International Meteorological Congress held at Chicago in August, 1893. This paper was translated from the Spanish by Dr. C. Findlay, of Habana, who as a friend of Father Viñes secured a revision of the translation, except the last few pages be-

[5] Viñes Benito: Investigation of the cyclonic circulation and translatory movement of West Indian hurricanes, W. B., No. 168, Washington, 1898.

fore the death of the author. It was published by the Weather Bureau as an extract from Weather Bureau Bulletin No. 11. Some of the conclusions of Father Viñes are summarized in the following paragraphs:

In the West Indian cyclones the rotation and the cyclonic circulation take place in such a manner that the inferior currents, as a rule, converge more or less toward the vortex; at a certain altitude the currents follow a nearly circular course, and higher still their course is divergent. It is particularly to be noticed that this divergence is all the greater as the currents occupy higher altitudes, until a point is reached where the highest cirrus clouds are seen to move in a completely divergent radial direction.

Thus, if the vortex lie due south, the wind will blow more or less from the east-northeast, the lowest clouds will move from the east, the alto-cumulus clouds from the east-southeast, the dense cirro-stratus from the southeast, the cirro-cumulus from the south-southeast, and the light cirrus from the south.

This graduation of the currents is of invariable occurrence, with greater or less perfection, in our West Indian cyclones, even when they present such incomplete organization as to be considered simple cyclonic perturbations of slight intensity. It constitutes what I have denominated *the law of cyclonic currents at different altitudes*, a truly admirable law which is undoubtedly founded on the very nature of the cyclonic movement and on the essential mechanism of the storm, and, in my opinion, constitutes the *fundamental law of the cyclonic circulation.* * * * To sum up briefly, we find that the cyclonic currents which exhibit the greatest regularity and point out best the bearing of the vortex are those of the cirrus and of the low clouds. The current of the cirrus clouds is that which should be selected in preference when the first indications of the approach of a cyclone are seen and the vortex is still far distant. In the interior of a storm the observer must be guided principally by the movement of the low clouds. In the absence of cirrus clouds the currents of the cirro-cumulus and cirro-stratus may guide one, and when there are no low clouds the wind and the high cumulus may be resorted to instead, always bearing in mind, however, that these indications are less reliable and the approximate inferences less satisfactory.

Many others have contributed to our knowledge of the forecasting value of accurate and detailed observations of the movement of high clouds. Boyer,[6] whose studies were made at Key West, Fla., was in a position to supplement those of Father Viñes, since both had practically the same geographical district as a background. Another careful observer who should be placed in the same category is Mr. John T. Quin, editor of Avis, Christiansted, St. Croix, Virgin Islands. Mr. Quin's contributions may be found in the MONTHLY WEATHER REVIEW for 1904, 1907, and 1909, volumes 32, 35, and 37. The observations of Mr. Quin lead to the conclusion that some of the earlier results of Father Viñes should be modified in the light of additional observations. Garriott[7] also questions the accuracy of Father Viñes conclusions regarding a divergent radial direction of cyclonic currents in high altitudes.

In the Far East may be mentioned the names of Fathers Algue, Faura, Froc, and others as students of clouds in connection with the advent of a typhoon. The first named of these devotes much space to the subject in his work on "Cyclones in the Far East," to which the reader must be referred for the details and conclusions. Father Algue, however, points out that not all Ci. and Ci.-St. are precursors of cyclones; much depends upon their being convergent and then showing a certain definite disposition.

Squally weather.—A rather reliable indication of the development or approach of a tropical cyclone is an unsettled and squally condition of the weather. Showers and squalls are usually experienced from 24 to 48 hours in advance of the storm proper. The following paragraphs from Eliot's Handbook of Cyclonic Storms in the Bay of Bengal[8] concerning the relation between squally weather and cyclones, while based upon a study of the storms over a particular area, perhaps are quite as applicable to tropical cyclones in other parts of the Northern Hemisphere:

It should be kept carefully in view by mariners of the Bay of Bengal that the formation of a cyclonic storm is a gradual process, and that it is only when the disturbance has passed beyond the initial stages that it becomes a storm in the proper sense of the word. The formation of a large storm is due to the prolonged continuance of actions, processes, and changes of the same kind as those that are occurring in the atmosphere at all times when rain is falling and strongish humid winds are blowing. Whatever the causes and origin of cyclones may be, the history of all cyclones in the Bay of Bengal shows that they are invariably preceded for longer or shorter periods by unsettled, squally weather, and that during this period the air over a considerable portion of the bay is gradually given a rapid rotary motion about a definite center. During the preliminary period of change from slightly unsettled and threatening weather to the formation of a storm, more or less dangerous to shipping, one of the most important and striking points is the increase in the number and strength of the squalls, which are an invariable feature in cyclonic storms from the very earliest stages. First of all, the squalls are comparatively light and are separated by longish intervals of fine weather and light variable or steady winds, according to the time of year. They become more frequent and come down more fiercely and strongly with the gradual development of the storm.

The area of unsettled and squally weather also extends in all directions, and usually most slowly to the north and west. If the unsettled weather advances beyond this stage (which it does not necessarily do), it is shown most clearly by the wind directions over the area of squalls. The winds always settle down into those which invariably occur over an area of barometric depression or cyclonic circulation, or, in other words, are changed into the cyclonic winds of indraft to a central area of low barometer and heavy rain. As soon as the wind directions indicate that a definite center of wind convergence has been formed in the bay, it is also found that the center never remains in the same position for any considerable interval of time, but that it moves or advances in some direction between northeast and west with velocities which not only differ very considerably in different storms, but also at different stages of the same storm.

The preliminary period of unsettled, squally weather may extend over several days, or may last only a few hours. It is, of course, impossible to determine exactly the hour at which the change from the antecedent disturbed squally weather to the cyclonic storm takes place. * * * These squalls are at first of short duration and comparatively feeble, but as they increase rapidly in frequency and intensity they are an almost certain indication of the commencement or of the existence of a cyclonic storm, and they become more and more prominent and more frequent and severe during the birth and growth of the cyclonic storm. It should, however, be carefully noted that squalls more or less severe occur under several sets of conditions, and it is hence desirable to discriminate between these. This is the more necessary in order that it may be fully realized that whilst squally weather is a necessary antecedent in time to the commencement of a cyclonic storm, squally weather is not necessarily followed by a cyclonic storm.

Thunderstorms.—Thunderstorms sometimes, but not always, accompany tropical cyclones, but as they occur during the storm and not before it begins, they can not be considered as precursory signs. Viñes[9] regarded them as evidence of the breaking away of the storm:

The absence of electrical discharges within the cyclone is a phenomenon so constantly observed that whenever during a tempest the rolling of thunder is heard or flashes of lightning are perceived this is considered as a favorable sign indicating the speedy disappearance of the storm. Especially among the country folk this opinion is general and deeply rooted. The crashing of thunder and the crowing of the cock are here the barometer of the farmer during cyclones, a barometer which, as he affirms, never deceives him. As long as the rooster does not crow, nor is there heard any peal of thunder, the storm will continue to rage in full force; but as soon as the lively crowing of the cock or the pealing of the thunder reaches his ear, the tempest, to his conviction, is about to pass away.

Ocean waves and swells.—An exhaustive study of the storm tides in connection with West Indian hurricanes was made by Cline,[10] and he arrived at the following conclusions:

[6] Boyer, H. B.: Atmospheric circulation in tropical cyclones as shown by movement of clouds. Weather Bureau, Washington, D. C., 1896.
[7] Garriott, E. B.: West Indian Hurricanes, Weather Bureau Bulletin H, p. 9.
[8] J. Eliot, second edition, 8vo., Calcutta, 1900-1901.
[9] B. Viñes S. J.: Apuntos sobre los huracanes de las Antillas. Habana, 1877, p. 190.
[10] I. M. Cline: MO. WEATHER REV., March, 1920, 48:127-146.

1. The waves and swells of greatest size and length are developed in the rear right-hand quadrant of the cyclonic area and move through the smaller waves in the front of the storm and are carried by inertia to the shore in the direction in which the cyclonic area was advancing at the time. The waves sent out in other directions, being smaller and shorter, do not persist long after leaving the cyclonic area and soon flatten out and disappear.

2. The transference of water with the long waves and swells causes rises in the water along the coast, which increase as the storm approaches. The rise in the water on the coast in front of the line of advance of the cyclonic area beginning 12 to 24 hours after the hurricane enters the Gulf of Mexico, indicates the rapid movement of the waves through the storm area and across the Gulf. * * * The speed varies from 30 to 45 miles an hour. The rapidity with which the waves travel depends both upon the extent of the cyclonic area and the intensity of the winds that develop the waves and swells. The water rises at the shore in the front, and to the right, of the point toward which the center of the hurricane was moving at the time the waves started on their journey.

3. The rise at shore of the water from the hurricane shows long in advance of any change in the barometer. Take for example the hurricane of September 11-14, 1919, when the barometer at Burrwood, New Orleans, Galveston, and Corpus Christi was either stationary or falling only a few hundredths of an inch, the water, first at Burrwood, later at Galveston, and then at Aransas Pass, was rising in feet telling the story of the movement and of the change in the course of the storm as plainly as could possibly be told.

4. In using the information conveyed by the tides in forecasting the movements of hurricanes, the tides as predicted by the Coast and Geodetic Survey should be plotted for each hour whenever a storm appears in the Gulf. The height of the tide above mean low tide should be telegraphed from coast stations with each observarion, and these should be plotted over the predicted tides. The place where the water exceeds the predicted tides and continues rising is in the line of advance of the hurricane at the time that water started on its journey.

5. The intensity and extent of the hurricane is indicated when the disturbance is at a considerable distance in space and time by the rapidity of the rise in the water and the extent of the coast over which the rise is taking place.

6. The time between the commencement of the rise in the water at shore and the arrival of the hurricane will depend upon the rapidity with which the cyclone area is advancing and the intensity of the hurricane.

7. If the point of greatest rise shifts to the right or left, this indicates that the storm is changing its course in that direction toward which the increased rise is taking place.

8. When the crest of the storm tide is coincident with the crest of the regular tide, the height of the water will be greater by more than 1 foot for hurricanes of equal intensity than when the crest of the storm tide is coincident with low tide, and in forecasting storm tides this must be borne in mind.

9. The regular tides are not obscured at any time by the storm tide except at or near the point where the center of the storm moves inland, and then for only about 12 hours before the passage of the center of the hurricane.

10. The highest water occurs a few miles to the right, and about the time of the passage of the center of the cyclonic area.

11. The high water extends for only a short distance to the left of the point where the center of the storm moves inland. High water, however, is experienced to the right of the center for a distance of 100 to 200 miles.

12. The water commences rising at the shore toward which the cyclonic area is advancing in less than 24 hours after the center of the cyclonic area has entered the Gulf. The waves and swells which give this rise must have moved through and out of the rear right-hand quadrant of the storm area within 12 to 15 hours after the center of the storm entered the Gulf of Mexico. This indicates that with a fetch of 150 to 200 miles in the rear right-hand quadrant of the cyclonic area the winds furnish sufficient energy to develop waves and swells of a size and length that travel 30 to 45 miles per hour, reaching the middle Gulf coast, 400 miles distant, in 10 to 15 hours, and the Texas coast, 800 miles distant, in 15 to 20 hours.

The fall of the barometer.—Fassig[11] says in regard to changes in the barometer, the wind and the clouds:

The premonitory signs enumerated above are the most important features of the weather conditions preceding the storm area proper and are generally observed at distances varying from 500 to 1,000 miles in advance of the center of a storm. Within the radius of a day's movement of the storm, or roughy,l from 300 to 400 miles from the center, other and more reliable signs become evident to the observer accustomed to the regular sequence of weather changes in the Tropics. The barometer begins to fall slowly but steadily, although the diurnal variation is still well marked; the wind begins to increase in force, obliterating normal diurnal changes, and backs to the east or northeast, if the observer is directly in the path of the storm, or changes from northeast to north and northwest if the path of the center of the storm lies north of the observer. At the same time the direction and velocity of the lower clouds show unmistakable evidence of the presence of a storm and the bearing of the center. When the storm center is still far distant, the phenomenon called the "bar of the cyclone" may frequently be seen. This is a dense mass of rain cloud formed about the center of the storm, giving the appearance of a huge bank of black clouds resting upon the horizon, which may retain its form unchanged for hours. It is usually most conspicuous about sunrise or sunset. When it is possible to observe this bar, the changes in its position at intervals of a few hours will enable the observer to determine the direction of movement of the storm.

In "Camps in the Caribbees", a narrative volume by the naturalist, F. A. Ober, published in 1880, the following is found (p. 179):

Immediately preceding the hurricanes, there arrive off the Caribbean coast (of Dominica) vast numbers of birds called,from their cries, "Twa-oo". They are said to be the harbingers of hurricanes, and only appear during the calms immediately before a storm. They cover the water in large flocks and come in from the desolate sandy islands where they breed. They are the sooty tern (the *Sterna fuliginosa*), but are known to the natives as "Hurricane birds." When I arrived in Dominica the sea was black with them, but on the morning after the storm they had disappeared, to a bird, as completely as though blown into another sphere.

AVERAGE 24-HOUR MOVEMENTS OF TROPICAL STORMS

In Table 1 the following data are given by months for the years 1887 to 1923, inclusive, for each 2½° square between longitudes 50° and 100° W. and latitudes 10° and 40° N.: (1) The number of centers of tropical storms observed within the square at 8 a. m., seventy-fifth meridian time (except in a very few instances when it was necessary to interpolate in order to secure sufficient data of fast moving storms); (2) the average azimuth of the position of the center of all storms 24 hours after having been observed within the square, in degrees reckoned for simplifying the computations, from the west, as zero, through north (an entry of 110 means that the average position of the centers of the storms 24 hours later is in a direction 20° E. of N.); (3) the average 24-hour movement, in miles, of the centers of all storms observed within the 2½° square.

The average, both unsmoothed and smoothed, 24-hour movements of tropical storms that originated during the months June to November, inclusive, are shown graphically in Figures 10 to 21, inclusive. The unsmoothed and the smoothed values for each month are shown on the same page the one above the other. Because the data for many of the 2½° squares were scanty, the smoothed averages were obtained by taking the average of all observations in each square for which data were available and for all adjacent squares for which data were available. The unsmoothed charts show the number of storms of record for each square. (See the figures at the ends of the arrows). The smoothed arrows do not indicate frequency. Proper weight was given to the number of observations in each square. The values thus obtained were entered on a map and lines of equal angular direction and lines of equal 24-hour movement were drawn, using a convenient numerical interval. From these lines the smoothed average values for each square were obtained by interpolation.

[11] O. L. Fassig: Hurricanes of the West Indies. Bulletin X, U. S. Weather Bureau. 4to., Washington, D. C., 1912.

TABLE 1.—*Average movement of tropical cyclones, 1887 to 1928, inclusive.*

Explanation of headings:

"No." = Number of observations (in each 2½° square) upon which averages are based.

"Dir." = Average direction of movement of storms, measured in degrees clockwise from west as zero azimuth from 2½° squares during succeeding 24 hours.

"Mov." = Average 24-hour movement of storms, measured in miles.

JUNE

North latitude	West longitude 100°-97.5°			97.5°-95°			95°-92.5°			92.5°-90°			90°-87.5°			87.5°-85°			85°-82.5°			82.5°-80°			80°-77.5°			77.5°-75°		
	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.
40°-37.5°																														
37.5°-35°							1	136	750																					
35°-32.5°																1	59	450				2	142	262	1	134	400			
32.5°-30°				1	104	350				1	150	700													1	151	350	2	110	300
30°-27.5°				1	86	225	1	114	225										3	96	342	1	38	250						
27.5°-25°				1	89	300	3	33	217	1	7	175	2	354	175	4	80	375	1	70	100	1	130	400	2	100	250			
25°-22.5°				2	85	200	1	58	150	1	14	175	2	80	288	3	74	233	6	73	229							1	39	200
22.5°-20°				1	73	150	2	45	275	2	89	225				1	65	350	1	66	250	2	85	212	1	5	175	1	6	175
20°-17.5°							1	132	225	3	32	200	2	37	188				3	78	317	1	76	175						
17.5°-15°													1	22	150	3	38	267	1	21	250									
15°-12.5°																			1	59	225	2	50	325						
12.5°-10°																						1	58	200						

JULY

North latitude	100°-97.5°			97.5°-95°			95°-92.5°			92.5°-90°			90°-87.5°			87.5°-85°			85°-82.5°			82.5°-80°			80°-77.5°			77.5°-75°		
	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.
40°-37.5°																												1	153	775
37.5°-35°																			1	155	775	1	156	775	2	279	1,325	2	65	350
35°-32.5°							1	163	575				1	163	125	2	122	100	1	94	500	1	50	200				1	3	100
32.5°-30°							1	111	200				1	70	125	1	9	200				1	2	250	3	65	225			
30°-27.5°							2	54	300				1	78	250	2	106	275							1	94	250	1	105	375
27.5°-25°							1	88	150	1	36	275	1	104	325	2	74	225							1	80	150	1	45	125
25°-22.5°							1	88	150	1	40	375	1	36	250	1	75	325	2	59	212									
22.5°-20°										1	10	400	2	58	312				2	51	225	1	46	250						
20°-17.5°																1	23	375	2	52	250	2	34	325						
17.5°-15°																			2	61	288	1	30	300	1	17	425	3	22	300
15°-12.5°																						2	54	250						
12.5°-10°																						1	70	200	1	48	275			

AUGUST

North latitude	100°-97.5°			97.5°-95°			95°-92.5°			92.5°-90°			90°-87.5°			87.5°-85°			85°-82.5°			82.5°-80°			80°-77.5°			77.5°-75°		
	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.
40°-37.5°																			1	145	500									
37.5°-35°				1	110	500							1	142	300													2	56	200
35°-32.5°							1	142	300	1	63	200				1	153	1,000	2	116	163	1	120	500				4	108	338
32.5°-30°				1	129	200				1	125	500	1	58	175							2	73	200	2	87	162	1	134	500
30°-27.5°				1	70	200	1	65	500	1	81	150	5	77	150	2	70	238				1	115	200	2	76	238	1	28	150
27.5°-25°							1	30	525	2	54	350	1	28	300	1	13	150	5	27	200	3	60	192	5	51	295	3	80	333
25°-22.5°							3	21	300	2	20	288	1	37	325				2	50	338	2	26	200	1	48	200	5	25	235
22.5°-20°							1	20	250				3	29	317	3	25	367	2	38	275	1	60	350	1	33	200	1	30	175
20°-17.5°																			2	21	338	3	33	408	3	15	350	1	20	350
17.5°-15°																						2	34	375	1	21	425			
15°-12.5°																														
12.5°-10°																														

SEPTEMBER

North latitude	100°-97.5°			97.5°-95°			95°-92.5°			92.5°-90°			90°-87.5°			87.5°-85°			85°-82.5°			82.5°-80°			80°-77.5°			77.5°-75°		
	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.
40°-37.5°																			2	110	450	1	126	700	2	98	850	4	125	575
37.5°-35°																1	126	400	1	93	500	2	130	575	4	115	656	3	112	408
35°-32.5°										2	110	175				2	117	200	2	140	438	2	88	350	3	141	608			
32.5°-30°										3	87	392	4	109	506	1	152	525	3	68	559	2	88	700	2	131	225	5	121	365
30°-27.5°							3	110	208	2	98	525	7	99	307	4	69	225	2	66	325	4	105	481	5	89	310	3	98	308
27.5°-25°				1	20	400	5	112	210	6	96	217	8	90	395	4	74	294	1	24	325	4	91	294	4	82	338	5	118	345
25°-22.5°				2	128	462	7	77	225	3	51	183	2	24	162	9	65	244	2	69	275	7	84	257	2	38	350	7	60	282
22.5°-20°				3	53	167	1	59	150	4	14	225	8	48	248	3	51	208	10	45	242	2	67	288	2	13	300	2	62	288
20°-17.5°							1	72	250				2	35	238	2	38	275	6	57	258	3	36	208	4	33	256	4	32	300
17.5°-15°													1	28	350				4	43	249	3	37	258	3	29	258	3	21	300
15°-12.5°																						4	58	212	1	50	100			
12.5°-10°																						3	64	242						

OCTOBER

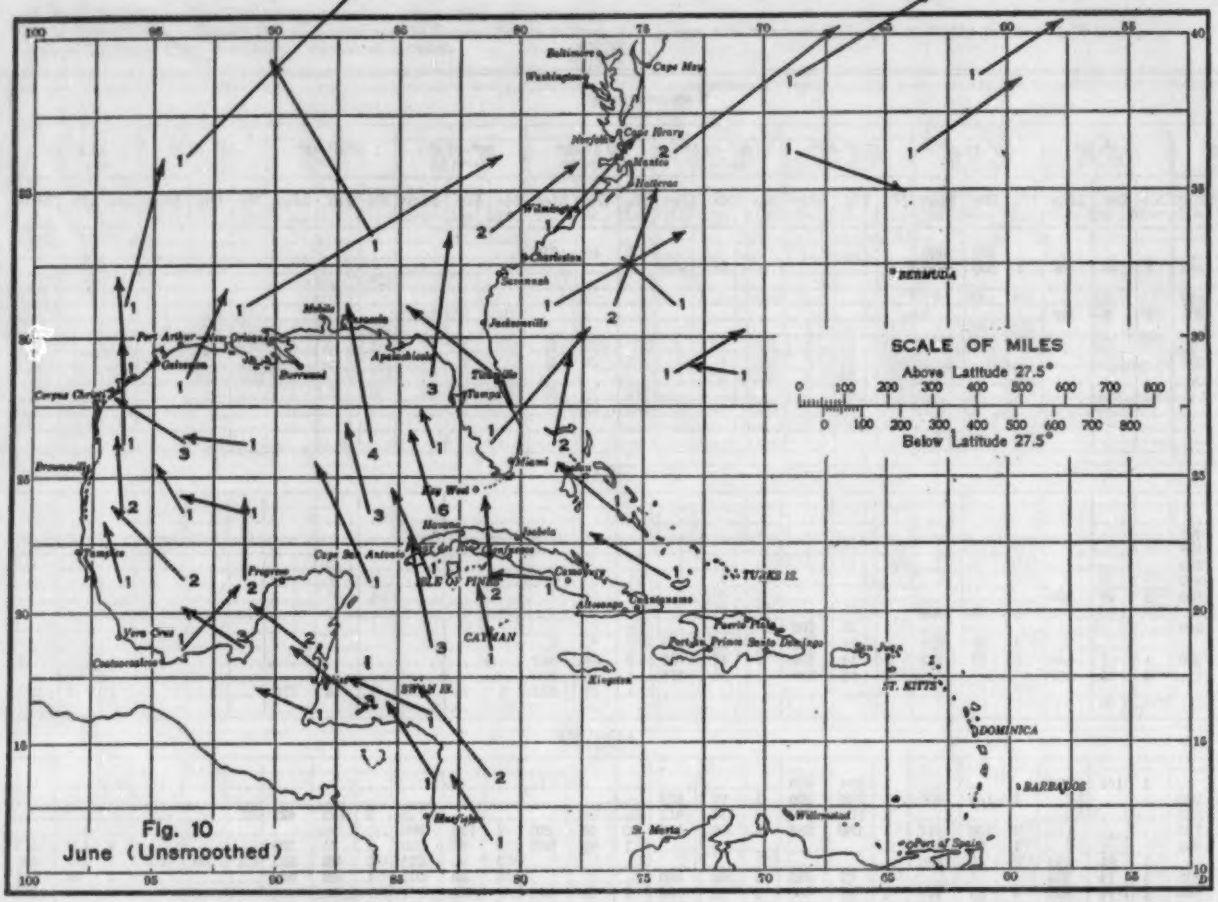
North latitude	100°-97.5°			97.5°-95°			95°-92.5°			92.5°-90°			90°-87.5°			87.5°-85°			85°-82.5°			82.5°-80°			80°-77.5°			77.5°-75°		
	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.
40°-37.5°																														
37.5°-35°																												1	102	400
35°-32.5°																			1	138	700				2	117	525	7	111	468
32.5°-50°										1	90	450				1	154	550	1	136	900	4	170	438	6	105	580	8	117	269
30°-27.5°													4	139	413	2	79	388	2	142	500	2	156	300	1	83	475	1	114	300
27.5°-25°				1	75	150				6	117	271	2	152	350	5	120	385	7	136	421	5	72	350	3	108	308	2	114	575
25°-22.5°							2	90	188	5	106	235	3	77	250	8	131	262	5	64	300	6	126	433	2	111	375	2	104	475
22.5°-20°							3	125	258	5	84	270	4	26	219	6	66	238	8	95	256	2	64	488	2	46	175			
20°-17.5°							1	26	225	2	66	200	1	2	325	8	51	262	11	55	189	7	38	214	3	44	175	1	35	350
17.5°-15°							1	100	400				1	28	275	1	102	200	4	45	281	9	53	186	7	41	168	3	50	283
15°-12.5°							1	68	200										1	26	300	5	65	230	3	78	235	1	23	225
12.5°-10°																									3	64	167			

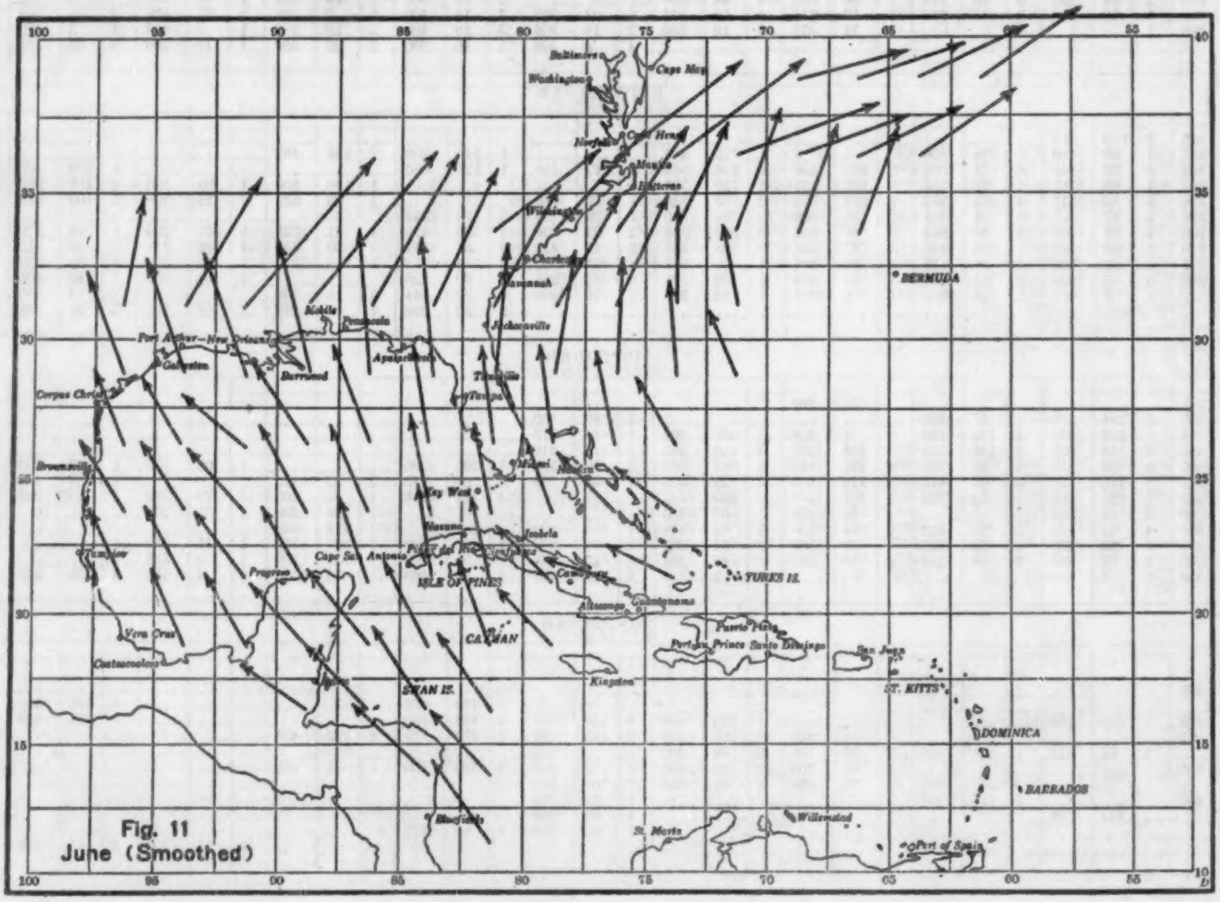
NOVEMBER

North latitude	100°-97.5°			97.5°-95°			95°-92.5°			92.5°-90°			90°-87.5°			87.5°-85°			85°-82.5°			82.5°-80°			80°-77.5°			77.5°-75°		
	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.
40°-37.5°																														
37.5°-35°																												2	134	950
35°-32.5°																									1	126	825	1	120	250
32.5°-30°																						1	128	800	1	115	400	1	98	125
30°-27.5°																						1	125	800	1	110	525	1	130	1,050
27.5°-25°																			3	143	900									
25°-22.5°																1	131	1,750							1	104	750	1	155	425
22.5°-20°																												1	145	500
20°-17.5°																1	100	200							3	133	142			
17.5°-15°																1	72	200				4	118	212	1	68	200	1	154	300
15°-12.5°																			1	44	250	3	74	350	2	114	188	1	143	350
12.5°-10°																						4	91	110	1	120	300			

TABLE 1.—*Average movement of tropical cyclones, 1887 to 1923, inclusive*—Continued.

West longitude																														North latitude
75°-72.5°			72.5°-70°			70°-67.5°			67.5°-65°			65°-62.5°			62.5°-60°			60°-57.5°			57.5°-55°			55°-52.5°			52.5°-50°			
No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	No.	Dir.	Mov.	
JUNE																														
						1	150	400							1	46	250													40°-37.5°.
2	143	488	1	143	150	1	200	275				1	145	300																37.5°-35°.
																														35°-32.5°.
1	41	150																												32.5°-30°.
1	150	200	1	8	125																									30°-27.5°.
																														27.5°-25°.
																														25°-22.5°.
1	29	250																												22.5°-20°.
																														20°-17.5°.
																														17.5°-15°.
																														15°-12.5°.
																														12.5°-10°.
JULY																														
																														40°-37.5°.
1	108	475																												37.5°-35°.
2	64	188																												35°-32.5°.
1	115	325																												32.5°-30°.
3	43	217																												30°-27.5°.
3	77	300	2	48	300																									27.5°-25°.
						1	50	300																						25°-22.5°.
1	75	350							1	55	200																			22.5°-20°.
						2	38	512	1	53	150	1	59	150																20°-17.5°.
1	5	200	1	7	150	2	12	112	1	14	100	1	44	400	2	36	362													17.5°-15°.
			3	13	367				4	14	319	1	30	175	3	15	350													15°-12.5°.
															1	12	375	1	16	275	1	16	275				1	17	275	12.5°-10°.
AUGUST																														
			1	167	300				1	164	375																			40°-37.5°.
1	144	200				1	153	650	1	136	300	1	92	375																37.5°-35°.
1	84	625							2	102	312	3	111	417							2	143	425							35°-32.5°.
1	63	125				3	136	417	4	120	238	3	338	100	2	56	250	1	114	300										32.5°-30°.
3	84	233				1	95	400							1	62	300	2	80	300	1	75	250				1	124	450	30°-27.5°.
			3	81	392	2	55	350										1	90	275	3	32	333	1	40	225	1	358	400	27.5°-25°.
5	38	320	3	11	233				2	62	425	1	356	450				1	66	275	1	52	300				1	50	250	25°-22.5°.
2	34	600	2	74	325	1	20	275	2	26	600	2	32	500	1	28	375										2	46	375	22.5°-20°.
1	23	250	2	64	200	3	28	317	5	30	305	2	40	288				2	22	300	2	19	262	1	40	450				20°-17.5°.
4	16	450	4	18	456	3	13	358	3	19	375	5	12	355	3	27	283	7	15	400	1	7	250	2	21	438	2	15	288	17.5°-15°.
2	18	600							3	11	475	2	19	350	3	13	358	3	19	400	2	10	338	1	3	450	1	5	400	15°-12.5°.
															1	8	400	1	10	500	2	27	350	1	17	200	2	30	325	12.5°-10°.
SEPTEMBER																														
4	61	456	3	109	517																									40°-37.5°.
5	78	450	1	62	100	1	126	300				1	121	350				1	140	200	2	138	462							37.5°-35°.
2	146	462	3	97	342	4	123	500	2	108	500	6	116	346	1	147	450	1	125	800							1	130	300	35°-32.5°.
4	108	362	4	83	381	6	92	284	2	135	425	4	139	537							1	150	550	1	98	500	2	116	362	32.5°-30°.
2	135	338	3	45	317	4	102	319	5	113	305	2	62	338	1	57	250				1	85	625	2	75	300	1	102	350	30°-27.5°.
2	64	388	5	62	295	6	78	258	2	39	200	2	54	300	1	56	250	2	78	338										27.5°-25°.
1	2	200	3	53	292	6	58	333	5	67	305	2	28	238	2	22	200	1	28	425	1	41	225	1	75	300	1	76	375	25°-22.5°.
5	39	310	6	39	292	1	10	325	4	47	281	7	48	307	2	45	312	2	37	212	2	60	350	3	22	317	2	66	312	22.5°-20°.
2	21	275	2	26	325	4	34	288	3	44	384	6	37	275	4	27	382	5	23	315	3	15	350	1	52	225	4	30	312	20°-17.5°.
5	13	300	5	8	320	4	13	281	7	14	304	7	22	206	6	15	254	3	30	225				2	34	202	1	43	600	17.5°-15°.
			1	6	475	1	4	325	1	8	275	1	52	375	7	21	296	4	22	344	3	19	292				2	29	212	15°-12.5°.
																		3	32	292	1	42	275	3	25	275	3	21	284	12.5°-10°.
OCTOBER																														
									1	167	350																			40°-37.5°.
2	206	350	3	134	375	1	67	450							1	62	500													37.5°-35°.
7	119	214	1	350	175	4	128	606	1	73	400	1	126	500	1	44	375													35°-32.5°.
1	165	625	2	110	650	3	156	325	3	139	258	3	110	367	2	171	312													32.5°-30°.
8	141	400	3	72	333	4	59	331	4	101	450	2	19	262	3	90	367	1	205	200				1	160	200	1	160	200	30°-27.5°.
4	129	318	1	113	525	3	69	417	2	116	300	4	33	300	1	80	500	3	67	575	2	92	425				2	62	400	27.5°-25°.
3	97	342	1	134	400	1	90	225	1	89	375	2	109	312				2	34	388	1	55	200	2	72	212	1	350	200	25°-22.5°.
2	83	300	2	84	525				2	88	425	1	67	350							1	75	300	1	55	200				22.5°-20°.
1	105	525	4	32	375	2	27	312	3	49	358	2	50	438	1	5	400				1	112	325							20°-17.5°.
2	14	275	3	20	308	2	22	300	1	28	300	6	34	284	2	24	238	1	23	500	1	97	350	1	55	450				17.5°-15°.
1	15	300	1	13	300	2	8	288	4	10	306	4	45	294	6	19	246	1	23	200	2	52	300	1	0	350				15°-12.5°.
1	8	350	1	7	350							1	5	350	3	32	284	5	25	260	1	22	150	3	3	375	3	23	308	12.5°-10°.
NOVEMBER																														
																														40°-37.5°.
1	167	900																												37.5°-35°.
																		1	136	450							1	135	200	35°-32.5°.
1	107	475	1	130	700							1	115	550	2	118	700	1	152	500							1	108	250	32.5°-30°.
3	92	367							3	131	492	1	108	500	2	140	50	1	130	75	1	125	425							30°-27.5°.
			2	85	612	1	154	200	2	85	225	3	88	200																27.5°-25°.
2	58	400							2	96	250	1	82	500	1	10	200	1	120	400	1	13	175							25°-22.5°.
						1	117	250	1	26	450	1	60	250	1	103	300													22.5°-20°.
1	118	450				1	153	350							1	80	1,050													20°-17.5°.
			1	143	300										1	90	300													17.5°-15°.
															1	85	350	1	65	575										15°-12.5°.
																								1	17	350	1	12	250	12.5°-10°.


SCALE OF MILES
Above Latitude 27.5°
Below Latitude 27.5°
BERMUDA
TURKS IS.
ST. KITTS
DOMINICA
BARBADOS
SWAN IS.
CAYMAN
ISLE OF PINES
Fig. 10
June (Unsmoothed)


BERMUDA
TURKS IS.
ST. KITTS
DOMINICA
BARBADOS
SWAN IS.
CAYMAN
ISLE OF PINES
Fig. 11
June (Smoothed)

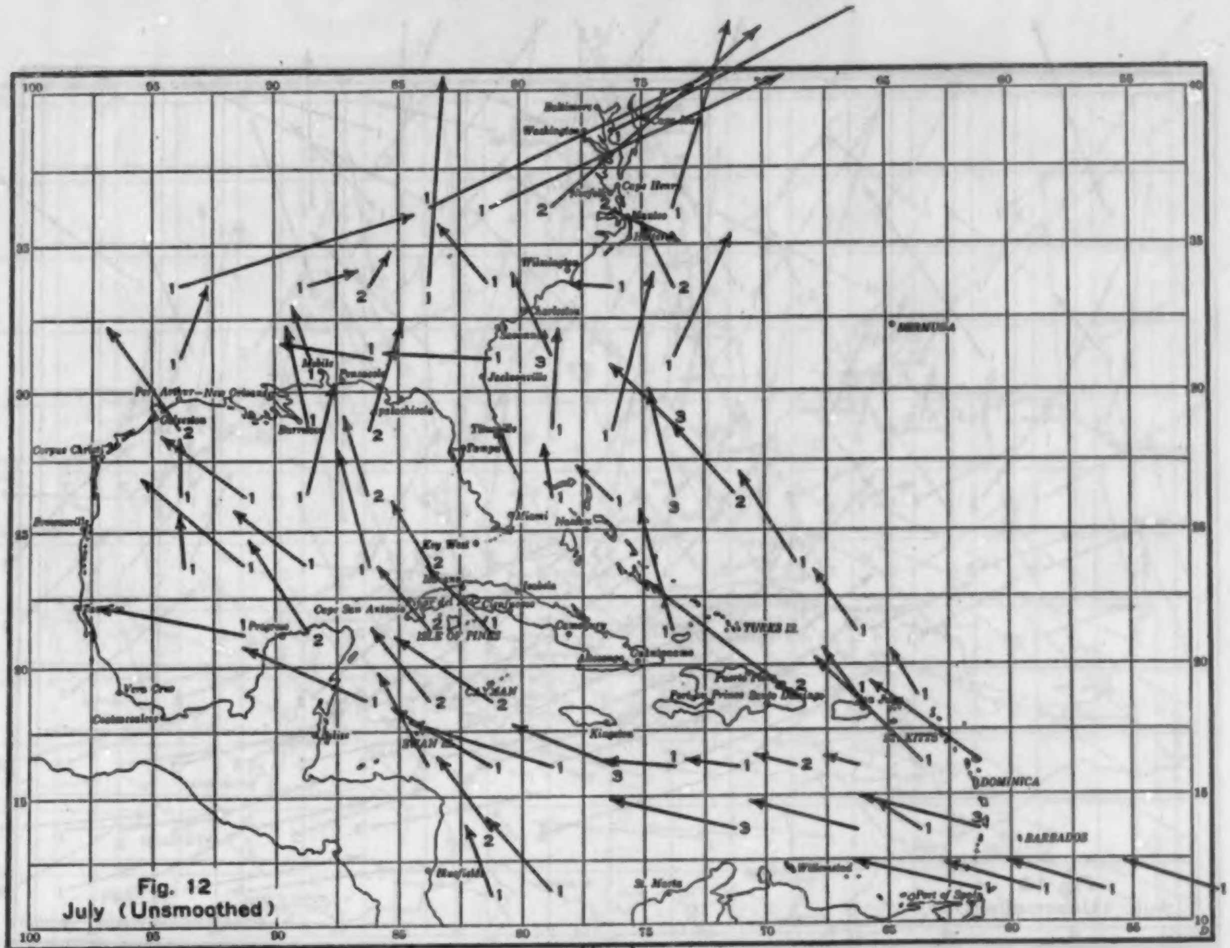


Fig. 12
July (Unsmoothed)

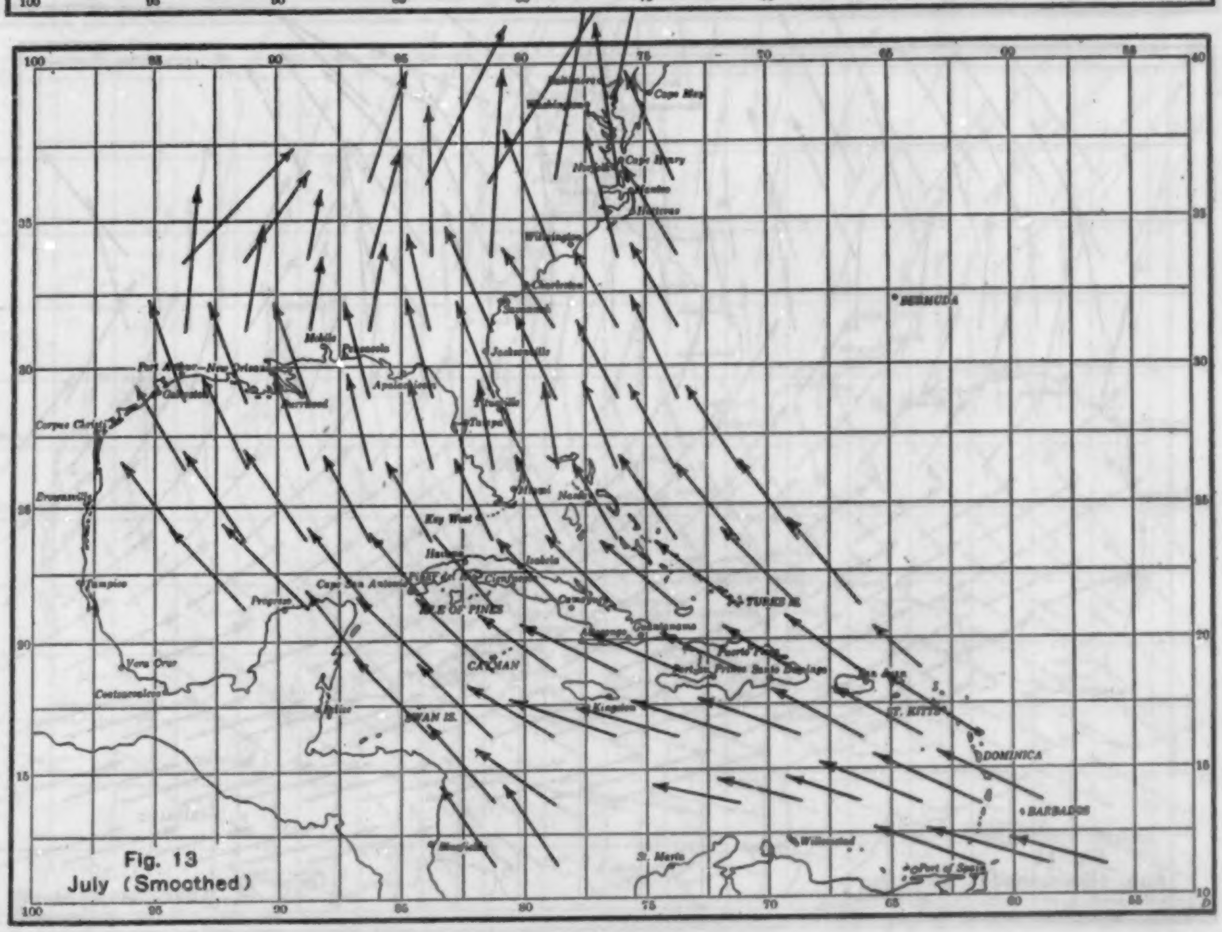


Fig. 13
July (Smoothed)

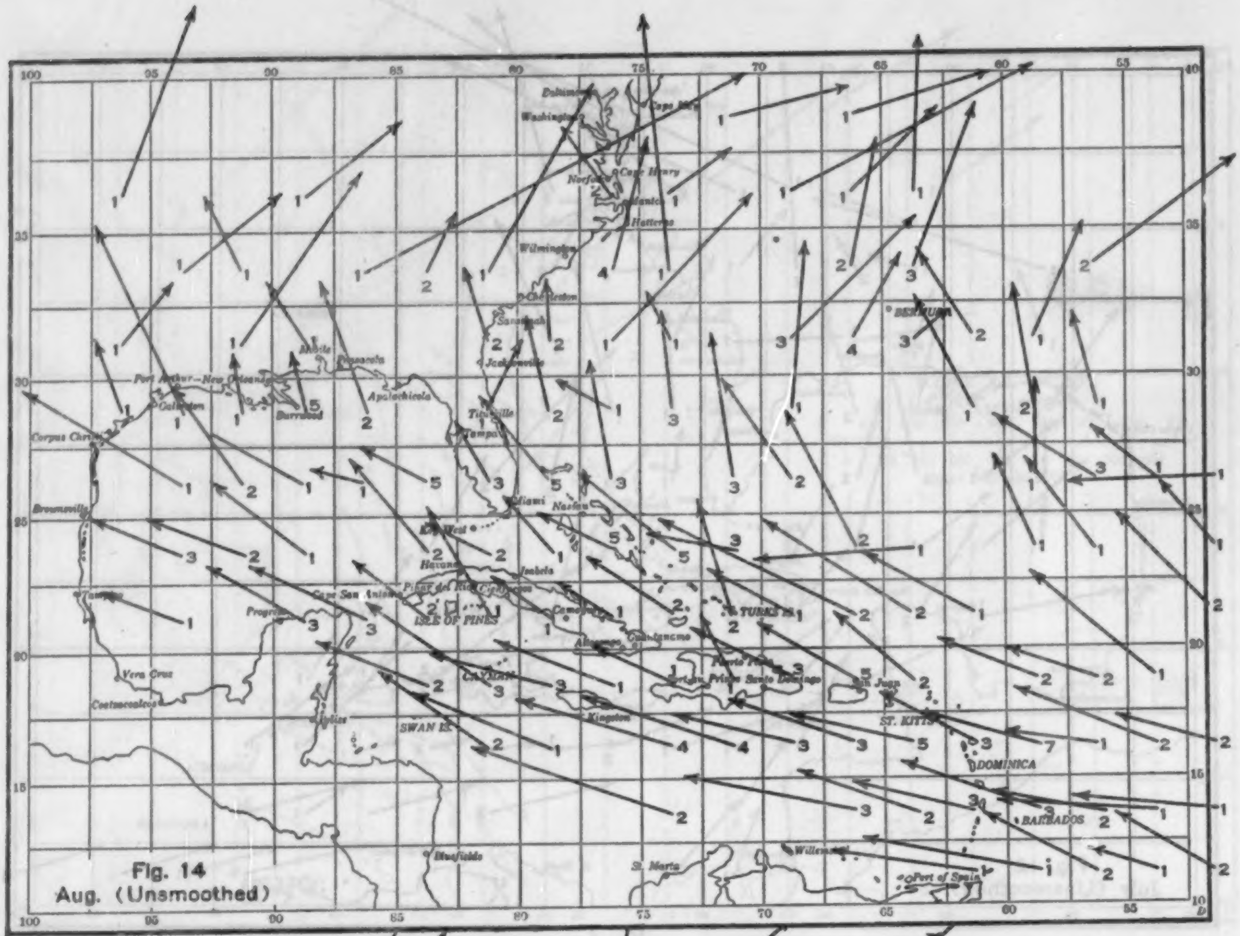


Fig. 14
Aug. (Unsmoothed)

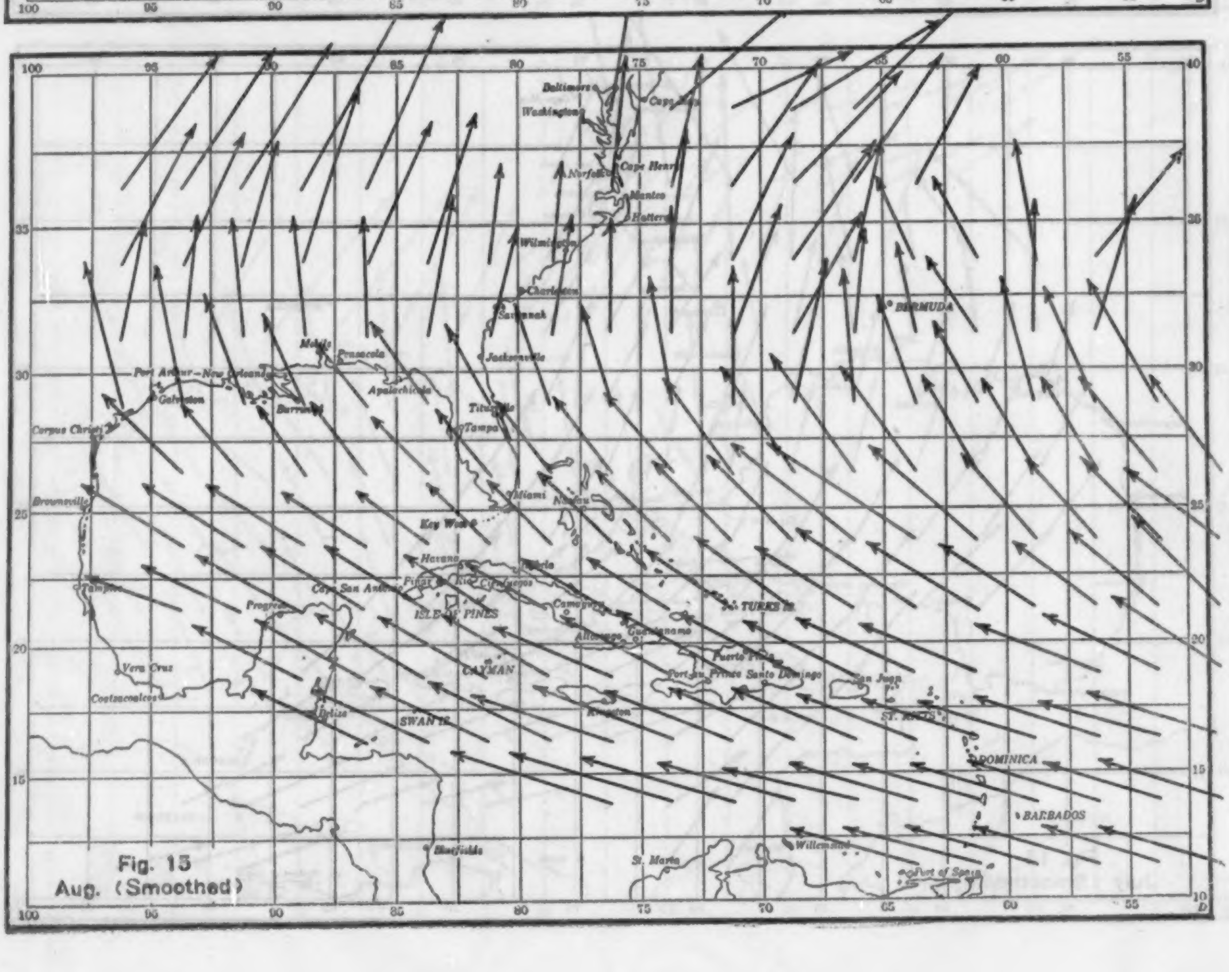


Fig. 15
Aug. (Smoothed)

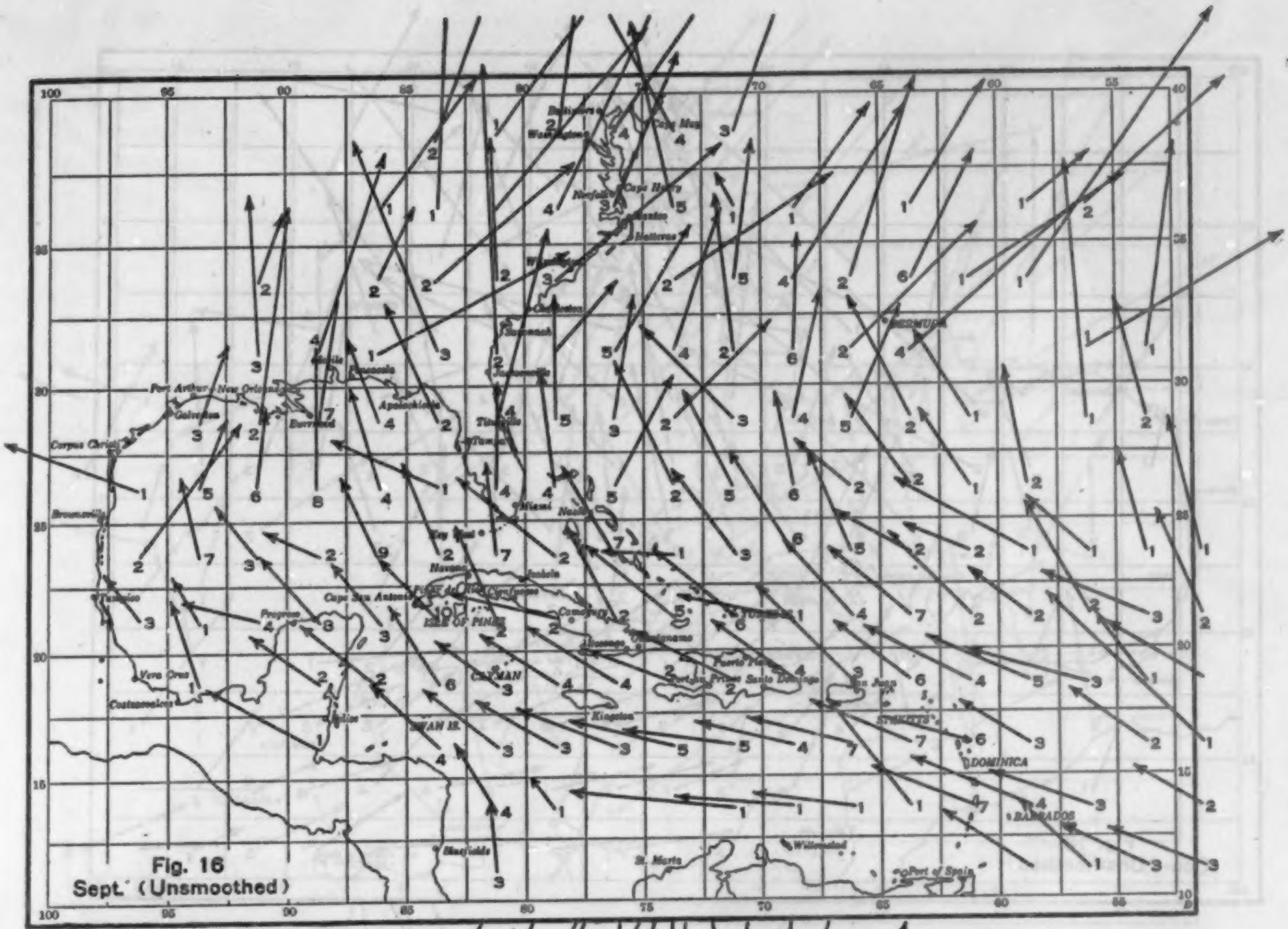


Fig. 16
Sept. (Unsmoothed)

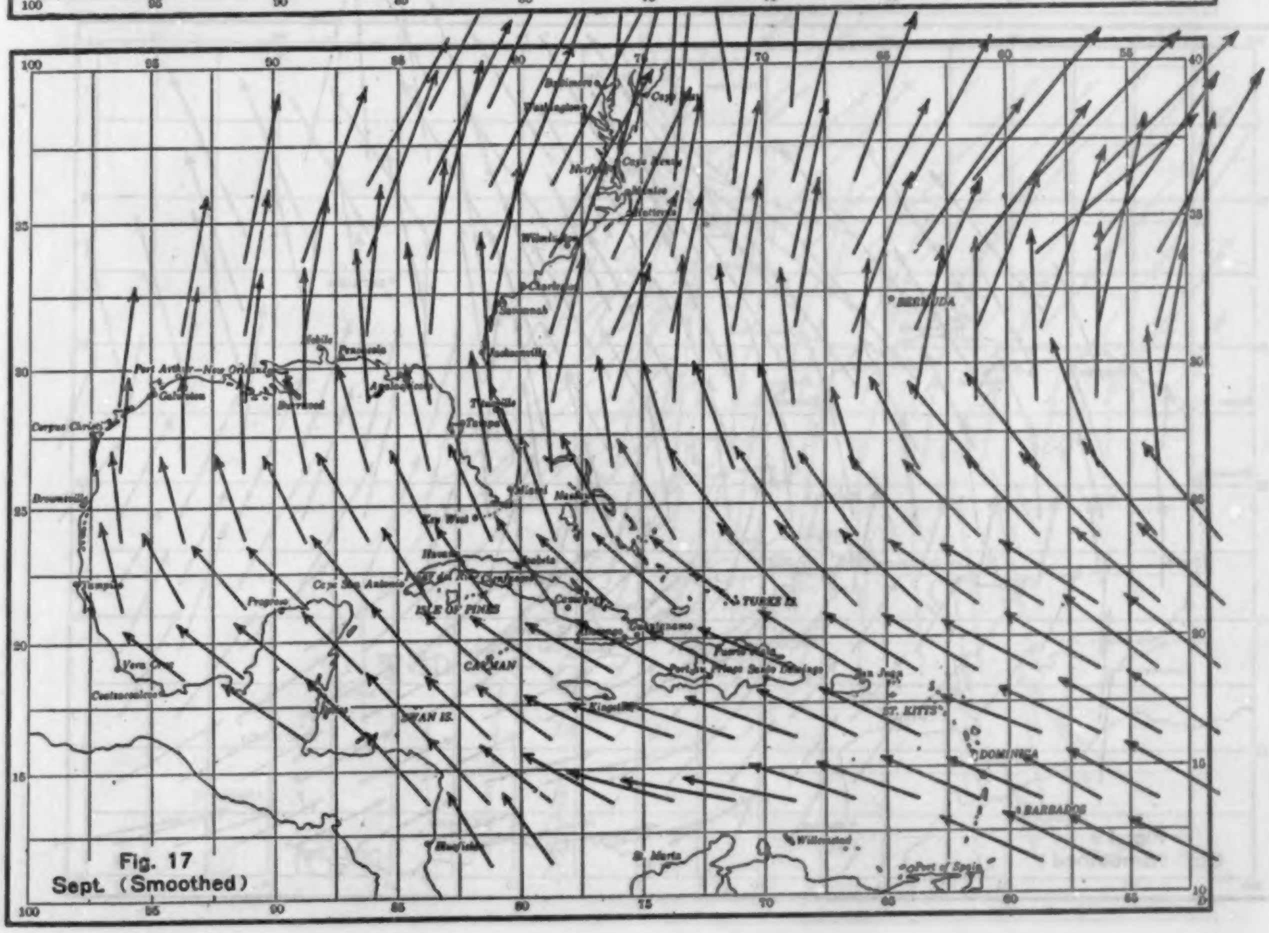


Fig. 17
Sept. (Smoothed)

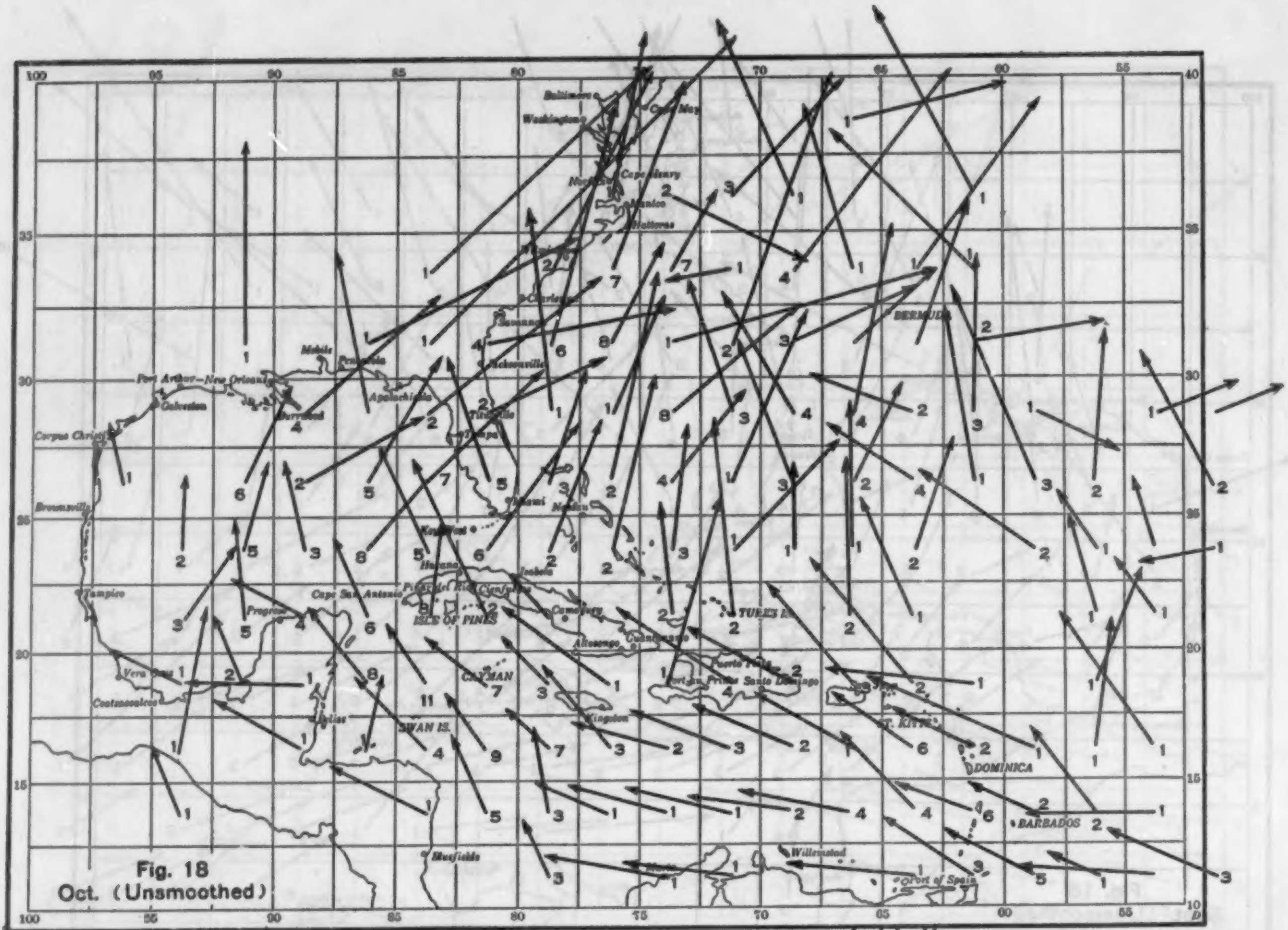


Fig. 18
Oct. (Unsmoothed)

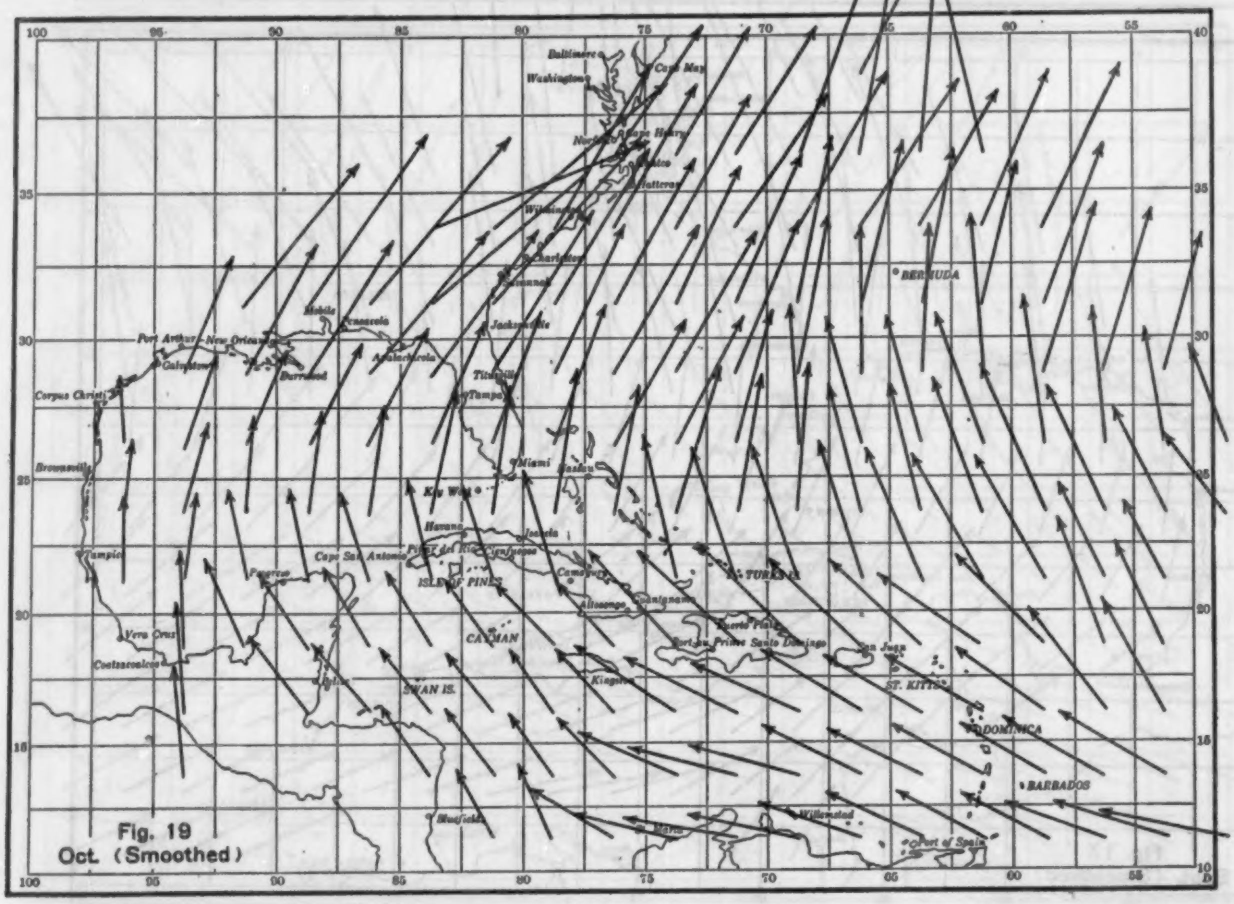


Fig. 19
Oct. (Smoothed)

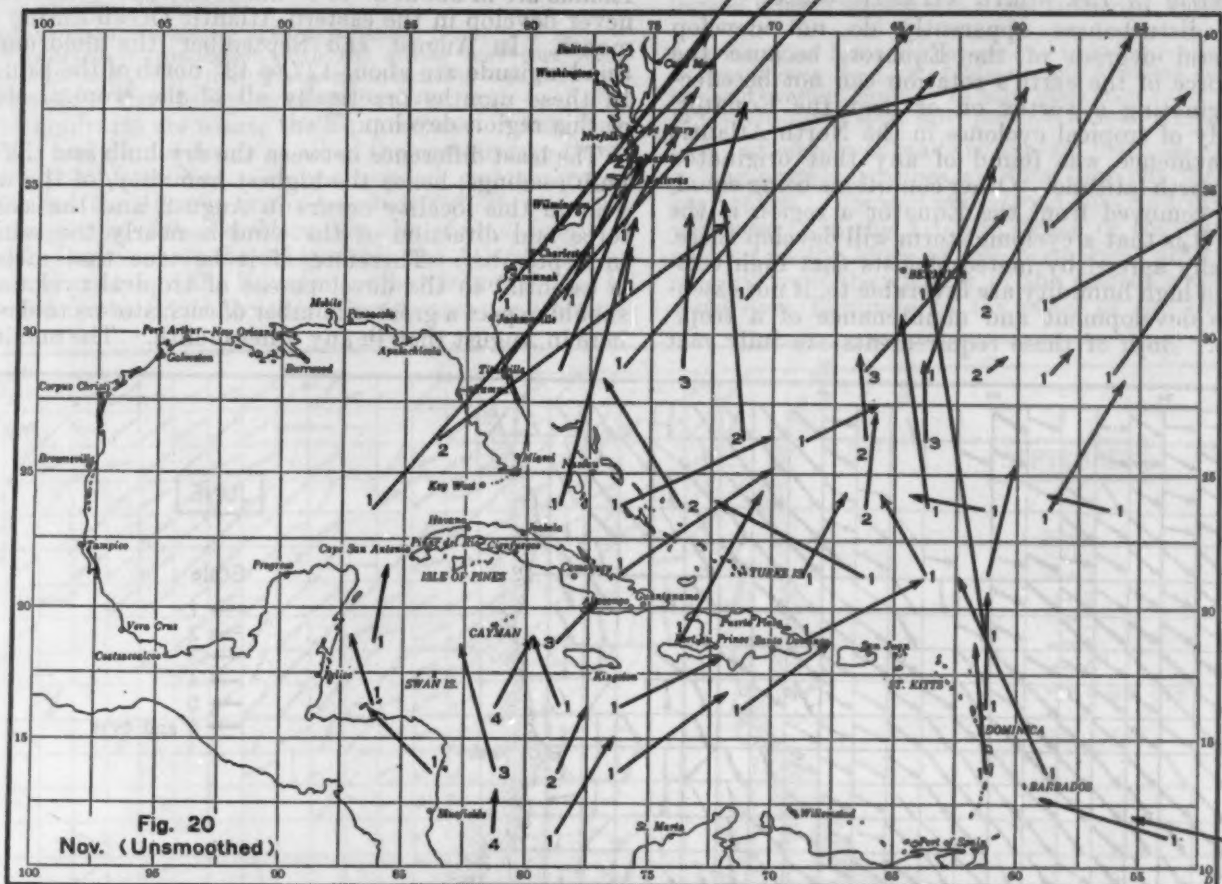


Fig. 20
Nov. (Unsmoothed)

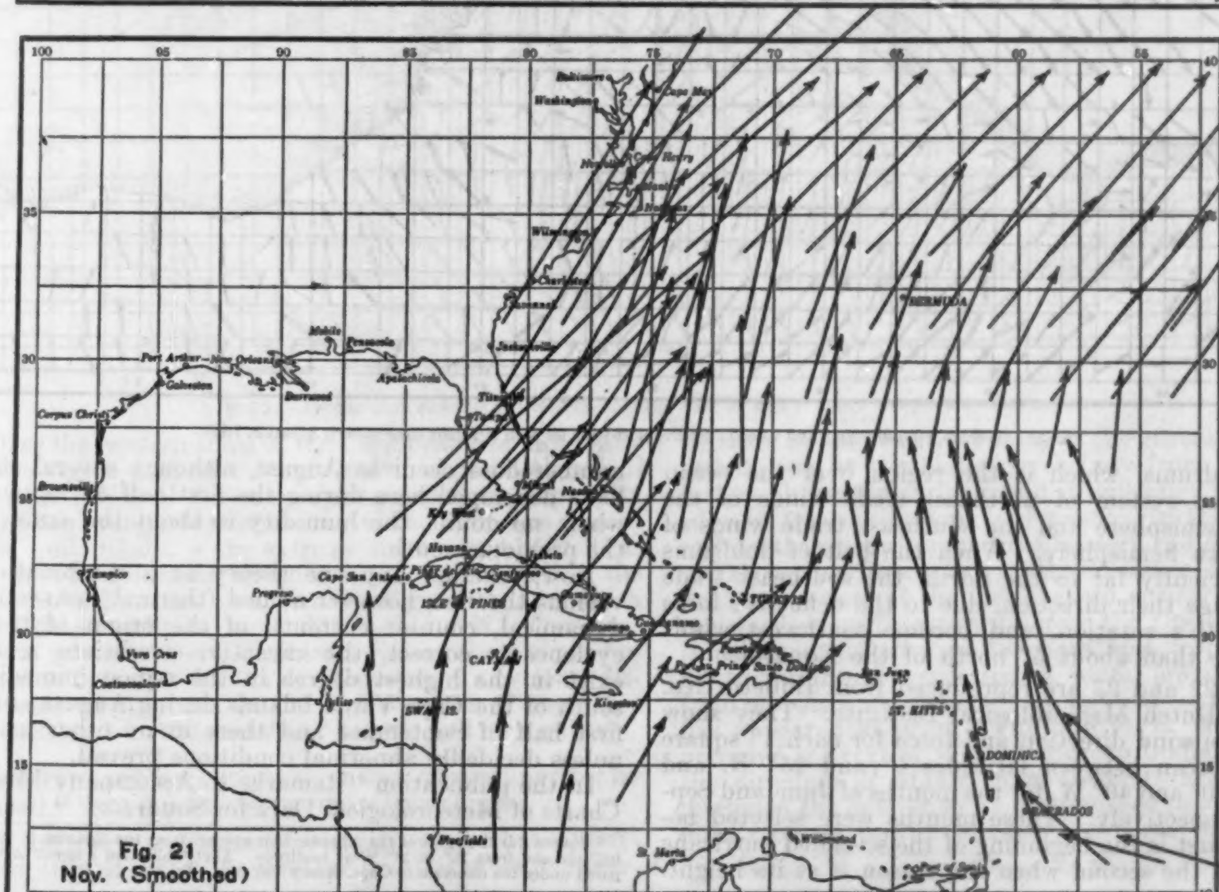


Fig. 21
Nov. (Smoothed)

THE TWO PRINCIPAL REGIONS WHERE TROPICAL CYCLONES DEVELOP IN THE NORTH ATLANTIC OCEAN

Cyclonic disturbances apparently do not develop within several degrees of the Equator, because the deflective force of the earth's rotation can not be effective in originating a vortex on or near the Equator. In this study of tropical cyclones in the North Atlantic Ocean no evidence was found of any that originated south of 9° north latitude. Other conditions being equal, the farther removed from the Equator a region is the more likely it is that a cyclonic storm will develop there. It is generally agreed by meteorologists that high temperature and high humidity are favorable to, if not essential, in the development and maintenance of a tropical cyclone. Both of these requirements are fully met in the doldrums, which is the region over the ocean between the system of northeast trade winds of the northern hemisphere and the southeast trade winds of the southern hemisphere. When the belt of doldrums shifts sufficiently far to the north, the southeast trade winds change their direction, due to the deflective force of the earth's rotation, and become southwest winds when more than about 5° north of the Equator.

Figures 22 and 23 are reproduced from Bulletin No. 95 of the Dutch Meteorological Institute. They show the average wind direction and force for each 1° square over the ocean between latitudes 0° and 25° N. and longitudes 0° and 40° W. for the months of June and September, respectively. These months were selected because the first is the beginning of the so-called hurricane season and the second when the season is at its height.

In June the doldrums in the longitude of the Cape Verde Islands are in about 8° to 9° north latitude. Hurricanes never develop in the eastern Atlantic Ocean during that month. In August and September the doldrums in this longitude are about 12° to 13° north of the Equator. In these months practically all of the tropical storms of this region develop.

The least difference between the dry-bulb and the wet-bulb readings, hence the highest humidity, of the whole year in this locality occurs in August, and the average force and direction of the wind is nearly the same as in September. Therefore, if it be true that moisture is essential to the development of tropical cyclones we should expect a greater number of such storms to develop here in August than in any other month. The maximum number does occur in August, although several storms have developed here during the first half of September, when, no doubt, the humidity is about the same as in the previous month.

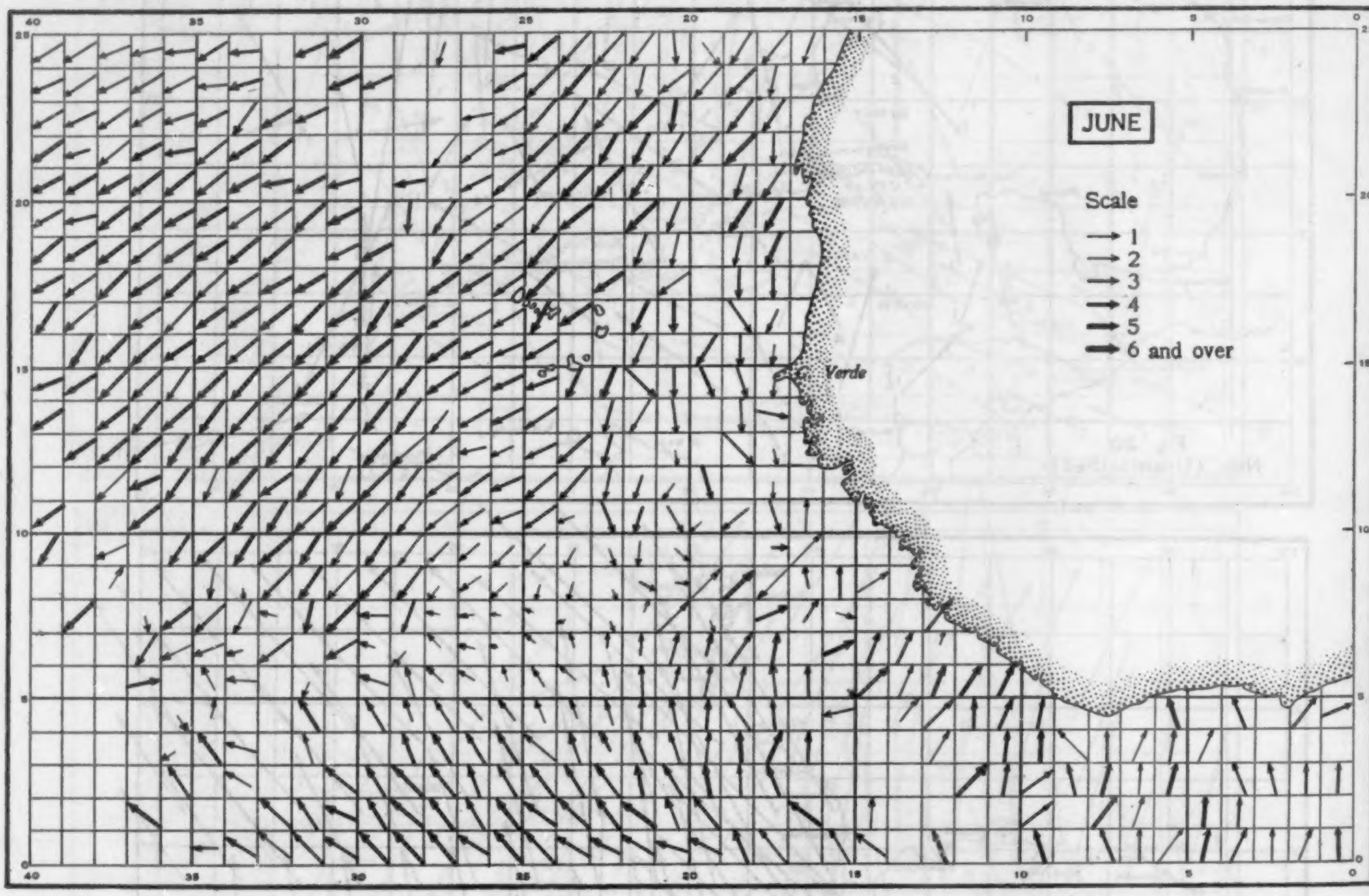


FIG. 22.—Average wind direction and velocity by Beaufort scale for each 1° square over eastern Atlantic, June

Now, whether any one theory or a combination of various theories, however named (thermal, convectional, dynamical, counter current), of the origin of tropical cyclones is correct, the causative conditions seem to exist in the highest degree in the region immediately south of the Cape Verde Islands during August and the first half of September and there in no other months, unless decidedly abnormal conditions prevail.

In the publication "Remarks to Accompany Monthly Charts of Meteorological Data for Square 3," [12] issued by

[12] Square 3 is that part of the Atlantic that extends from the Equator to 10° North latitude and from 20° to 30° West longitude. The publication referred to was prepared under the direction of Capt. Henry Toynbee.—Ed.

the Meteorological Office, London, in 1874, the following appears in regard to the weather conditions over the region referred to above:

The strong southwesterly gales experienced between 9° and 10° N., considered in connection with the strong northeast winds between 16° and 20° N., in August seem to indicate that the breeding place of the West Indian hurricanes lies between them. * * *

The doldrums are nearer the Equator west of longitude 30° W., and do not occur at all in the eastern two-thirds of the Caribbean Sea. Hence *tropical cyclones rarely develop over the Atlantic west of longitude 30° W., and never over the portion of the Caribbean Sea east of about longitude 78° W.* Inasmuch as the doldrums in the Atlantic Ocean are always north of the Equator, no hurricanes should be expected in the South Atlantic Ocean, and none occurs.

able influence on the course of hurricanes. In Weather Bureau Bulletin A, Summary of International Meteorological Observations, 1893, the following is found:

* * * Some of the more important storms that originate near the West Indies do not recurve to the northward, but move westward over the Gulf of Mexico and dissipate over Mexico or the southwestern States. In such cases high barometric pressure to the northward apparently prevents a recurve.

No attempt was made to explain just how high pressure to the northward does at times prevent the recurve of hurricanes. It is well understood that no tropical cyclone will recurve in the Atlantic Ocean or the Caribbean Sea so long as the more or less permanent anticyclone that extends from the vicinity of the Azores west-southwestward over Bermuda to the coast of the United States

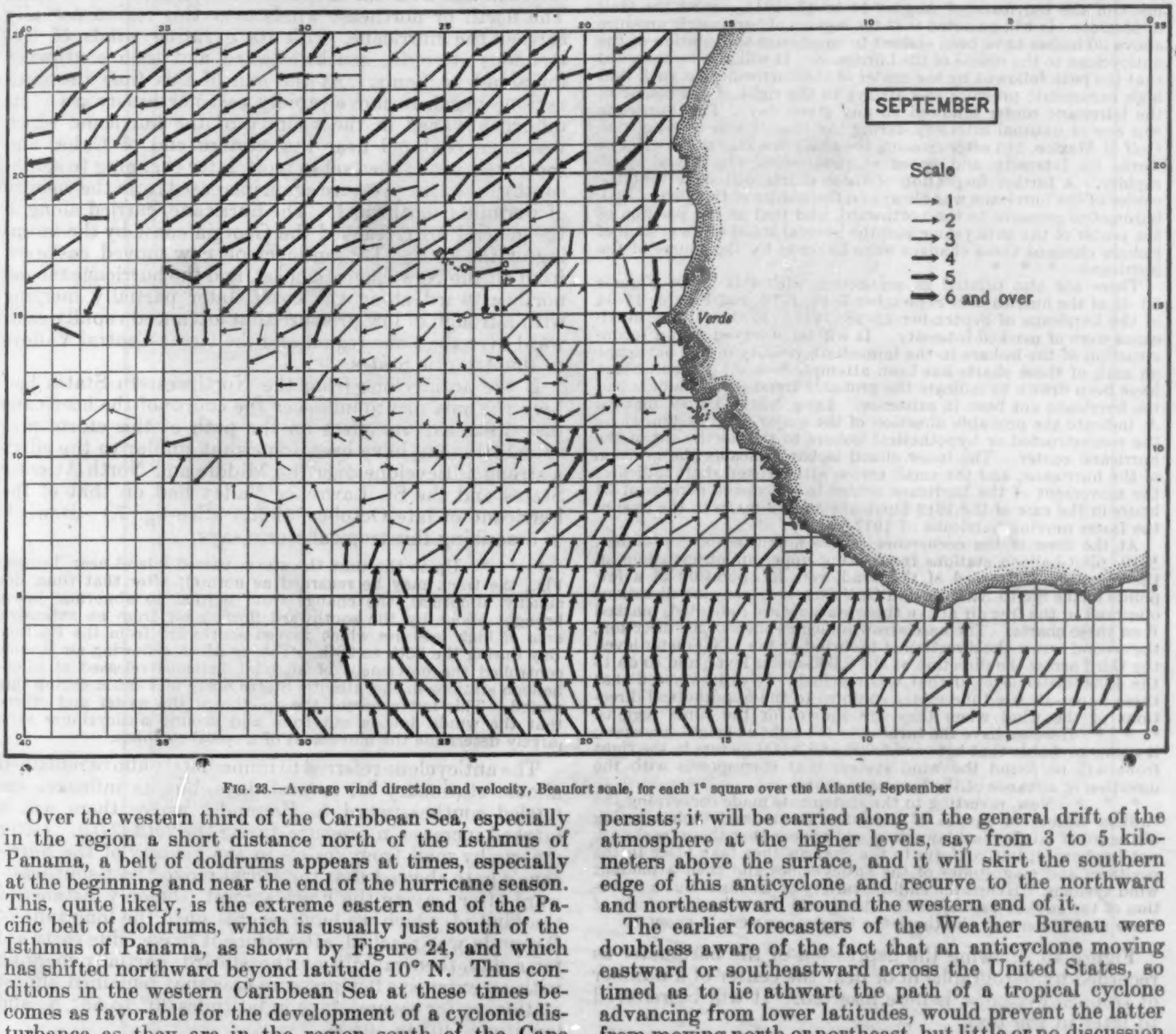


FIG. 23.—Average wind direction and velocity, Beaufort scale, for each 1° square over the Atlantic, September

Over the western third of the Caribbean Sea, especially in the region a short distance north of the Isthmus of Panama, a belt of doldrums appears at times, especially at the beginning and near the end of the hurricane season. This, quite likely, is the extreme eastern end of the Pacific belt of doldrums, which is usually just south of the Isthmus of Panama, as shown by Figure 24, and which has shifted northward beyond latitude 10° N. Thus conditions in the western Caribbean Sea at these times becomes as favorable for the development of a cyclonic disturbance as they are in the region south of the Cape Verde Islands in the months of August and September.

THE INFLUENCE OF ANTICYCLONES ON THE DIRECTION OF MOVEMENT OF TROPICAL CYCLONES

It has been recognized for many years that anticyclones (the HIGHS of the weather map) exercise consider-

persists; it will be carried along in the general drift of the atmosphere at the higher levels, say from 3 to 5 kilometers above the surface, and it will skirt the southern edge of this anticyclone and recurve to the northward and northeastward around the western end of it.

The earlier forecasters of the Weather Bureau were doubtless aware of the fact that an anticyclone moving eastward or southeastward across the United States, so timed as to lie athwart the path of a tropical cyclone advancing from lower latitudes, would prevent the latter from moving north or northeast, but little or no discussion has appeared in print. The late E. B. Garriott, who prepared the text of Weather Bureau Bulletin A [13] under the direction of Major (now General) Dunwoody has discussed the subject in an unpublished manuscript, and more recently Bowie [14] stressed the controlling influence

[13] Loc. cit. [14] E. H. Bowie: MO. WEATHER REV. 50:173-179.

of anticyclones and gave examples of their effect in preventing the recurve of tropical storms, as shown in the following extended excerpt from his paper:

* * * It is a generally recognized principle in weather forecasting that in the Northern Hemisphere a cyclone moves so as to keep the area of high barometer to the right of its course. In what has been said concerning the influence of anticyclones in determining the course or path of a cyclone or hurricane, I believe it should be understood that the writers had in mind the currents of air associated with anticyclones and not the actual differences in barometric pressure from cyclone center to anticyclone center. * * * It is, too, generally recognized that the position of an anticyclone in relation to the cyclone has a decided bearing not only on the direction of movement but also on the speed of movement of the cyclone. * * *

There are printed in connection with this paper Figures 25–32, showing the general distribution of pressure attending the movement of the hurricane of August 14 to 17, 1915, across the Gulf of Mexico. It will be noted that the regions of barometric pressure above 30 inches have been shaded to emphasize the relation of the anticyclone to the course of the hurricane. It will also be observed that the path followed by the center of the hurricane was such that high barometric pressure was always to the right of the course of the hurricane center followed on any given day. This hurricane was one of unusual intensity during the time it was crossing the Gulf of Mexico, but after crossing the coast line into the interior of Texas its intensity and speed of progression diminished quite rapidly. A further inspection of these charts will show that the center of the hurricane was always on the border of the area of high barometric pressure to the northward, and that as the position of the center of the anticyclone and the general trend of its system of isobars changed these changes were followed by the course of the hurricane. * * *

There are also printed in connection with this paper Figures 33–40 of the hurricane of September 7–14, 1919, and Figures 41–44 of the hurricane of September 25–28, 1917. Both of these hurricanes were of marked intensity. It will be observed that a reconstruction of the isobars in the immediate vicinity of the hurricane on each of these charts has been attempted—i. e., dotted isobars have been drawn to indicate the probable trend of the isobars had the hurricane not been in existence. Long, heavy arrows, marked A, indicate the probable direction of the major wind system along the reconstructed or hypothetical isobars to the northward of the hurricane center. The inner closed isobar indicates the position of the hurricane, and the small arrow with broken shaft indicates the movement of the hurricane center in successive periods of 24 hours in the case of the 1919 hurricane and 12 hours in the case of the faster moving hurricane of 1917.

At the time of the occurrence of the hurricane of September, 1919, pilot-balloon stations for making upper-air observations of the direction and speed of the wind were in operation at a few points in the South Atlantic and Gulf States. he wind directions observed in the free air above these stations are indicated, marked B on these charts. The base arrow indicates the surface direction, the second arrow the direction of the wind at the 1,000-meter level, the third arrow the direction at the 2,000-meter level, and so on to the 4,000-meter level, if that was reached. It will be noted that these upper-air wind directions conform to the hypothetical directions of the wind when they are shown for the same regions. * * * Here we have the turning to the right as height increases; it seems probable that between 3,000 and 4,000 meters in the right front will be found the wind system that corresponds with the direction of advance of the hurricane center.

* * * Now, reverting to the statements made concerning the endless variety of shapes of hurricane tracks and their seeming disregard of all physical laws, it would appear that these tracks are not haphazard, but conform to the changes that take place in the positions and magnitudes of the anticyclones and their attendant wind systems. Hence the endless variety of tracks is but a reflection of the endless variety of the changes in the isobaric systems of these anticyclones at the times the hurricanes were in progress.

Figure 45, showing the depression of the barometer as recorded by barographs in or near the center of a number of tropical cyclones, is here inserted. It will be referred to later in the text.

One of the best examples of the predominant influence of migrating anticyclones on the movement of a tropical cyclone is furnished by the abnormal track of the hurricane of October 12–21, 1910. (See figs. 46–53.) This hurricane originated in about latitude 13° N. and longitude 81° W. on the 11th and moved north-northwestward with normal speed until the night of the 14th–15th, when its northward progress was barred and its path deflected to the westward by the easterly winds at the intermediate levels, which winds, in turn, were controlled by an anticyclone that moved southeastward from western Ontario to the vicinity of Bermuda during the 12th–14th. It is only when the anticyclone controls the circulation up through a considerable distance, say, 3,000 or 4,000 meters at least, that it can change the course of a cyclone. By the morning of the 15th the anticyclone over Bermuda had weakened, but another, of wide extent, was central over Kansas, with increasing pressure, and moving southeastward toward the mouth of the Rio Grande. This anticyclone also controlled the circulation up to a considerable height as far as the southeastern Gulf of Mexico. The north or northeast winds over this region actually carried the hurricane, with its gyrating winds of tremendous strength, southwestward and then southward for about 24 hours. At the end of this time the anticyclone began to move rapidly east-northeastward. Its influence waned in the vicinity of the hurricane which was then centered near the western end of Cuba, and southwest winds then set in aloft, later changing to south-southwest as the pressure again increased from the vicinity of Bermuda southward. The hurricane, carried along in the general drift, reached the Georgia coast by the morning of the 19th. The anticyclone now moved eastward from off the New England coast, and the hurricane moved northeastward along the coast, later partially merging with a trough of low pressure that advanced rapidly eastward over the Lake region and the Great Central Valleys to the Atlantic States.

If the anticyclone from the Northwestern States had been the only one to influence the course of the hurricane just described, its effect on the path of this storm presumably would have been somewhat similar to the effect a strong anticyclone over the Middle and North Atlantic States and the St. Lawrence Valley had on that of the hurricane of late October, 1921. (See fig. 7.) Bowie[16] in describing this tropical storm says:

* * * Up to the time the storm passed inland near Tampa, Fla., the track may be regarded as normal; after that time, decidedly abnormal, the change from normal to abnormal being brought about by the southward flowing air from an extensive area of high pressure which moved southward from the Hudson Bay during the 25th to 28th. This southward flowing air stream controlled the movement of all pilot balloons released at pilot-balloon stations in the Atlantic States north of Florida during this period. This but confirms the opinion of the writer and others that the winds flowing out from and around anticyclones very largely determine the movement of tropical cyclones.

The anticyclone referred to immediately above remained almost stationary for several days, but its influence extended southeastward to Bermuda, where there was a marked increase in pressure during the 26th–27th. Later reports by mail from vessels in the vicinity of the hurricane's path showed that the storm moved east-southeastward after leaving the Florida coast (the only instance of the kind of which we have record) until the longitude of Bermuda was reached, after which it moved due eastward for a day, then rapidly northeastward, partially merging with an extensive low-pressure area that remained almost stationary for several days in latitudes 30° to 55° N. and longitudes 40° to 50° W.

Owing to the position and movement of two anticyclones that materially affected its course, the storm of October 2–11, 1913 (see figs. 54 to 65), moved in a decidedly abnormal path; in fact for a few days it

[16] E. H. Bowie: Mo. Weather Rev., October, 1921, 49: 567.

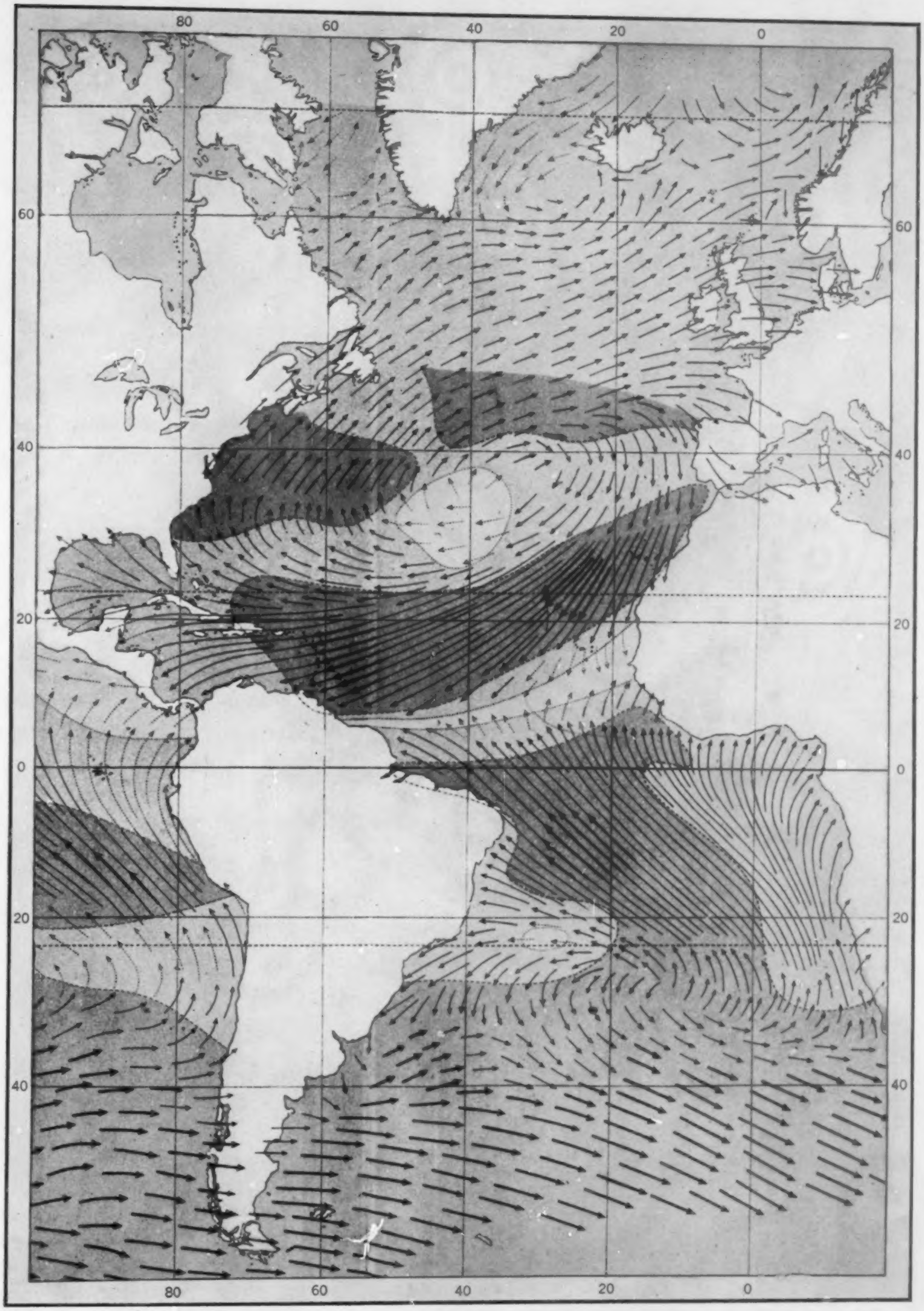


FIG. 24.—Winds over Atlantic Ocean, July and August (after Bartholomew's Physical Atlas, Vol. III, Plate 14)

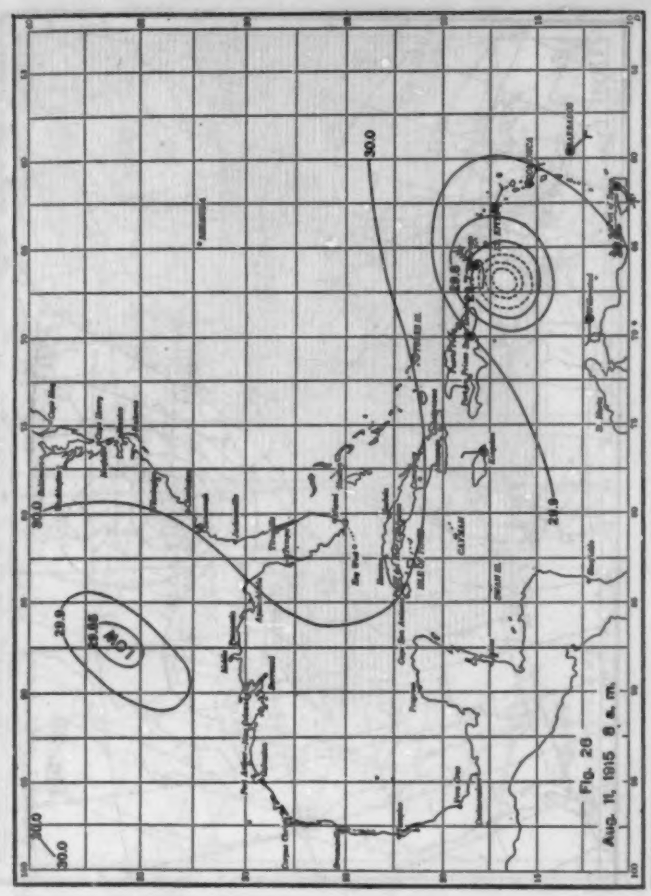


Fig. 26
Aug. 11, 1915 8 a.m.

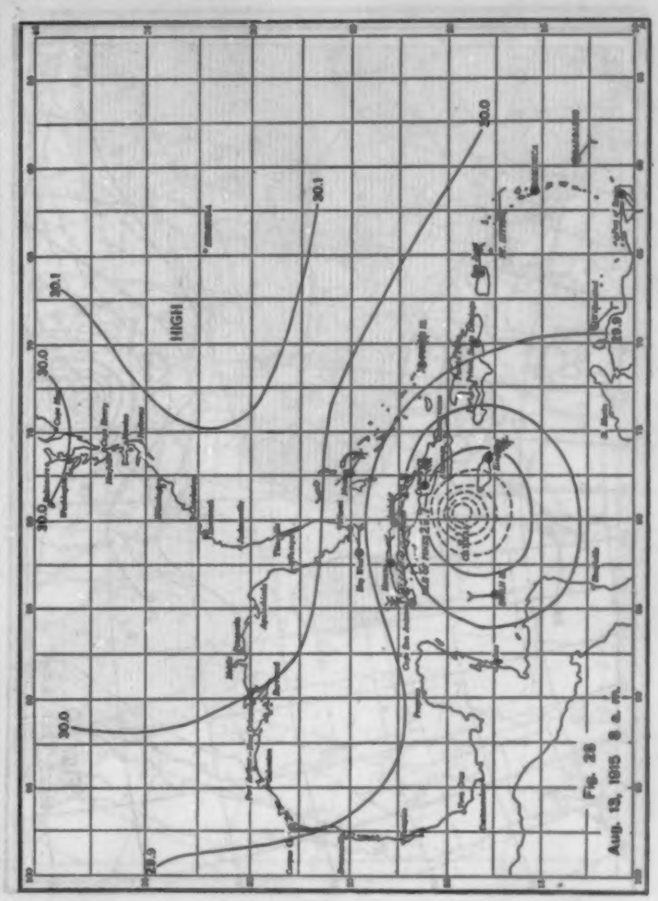


Fig. 28
Aug. 13, 1915 8 a.m.

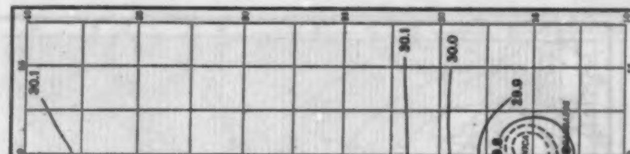


Fig. 25
Aug. 10, 1915 8 a.m.

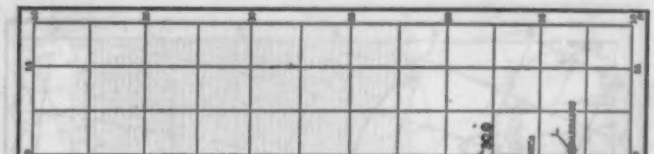


Fig. 27
Aug. 12, 1915 8 a.m.

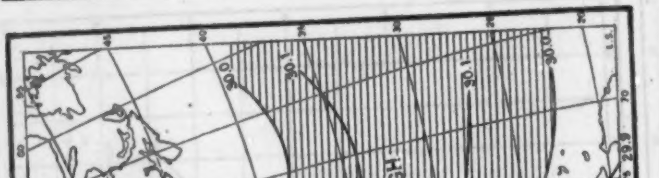


Fig. 29 August 14, 1915, 8 a.m.

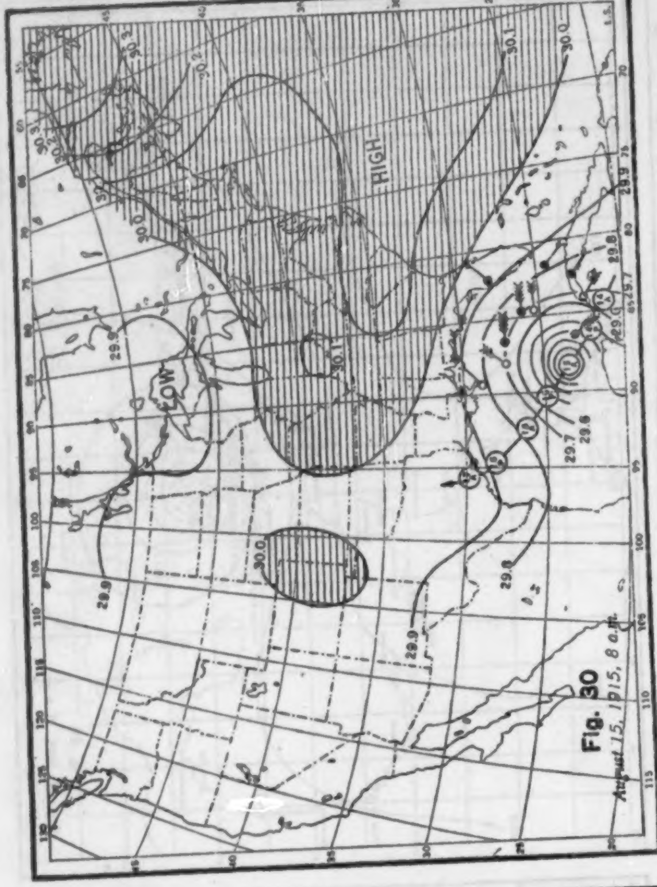


Fig. 30 August 15, 1915, 8 a.m.

Fig. 31 August 16, 1915, 8 a.m.

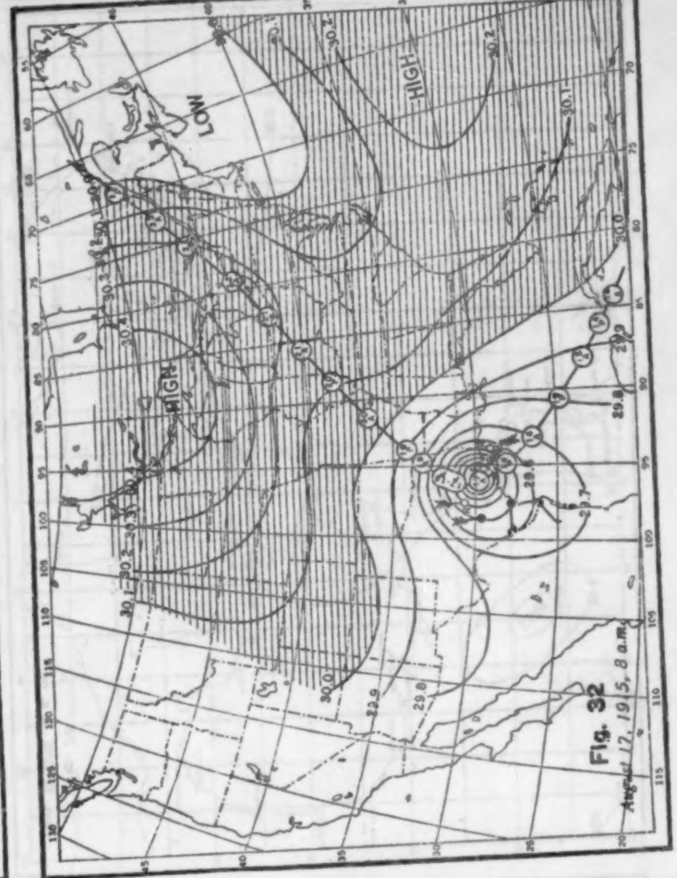


Fig. 32 August 17, 1915, 8 a.m.

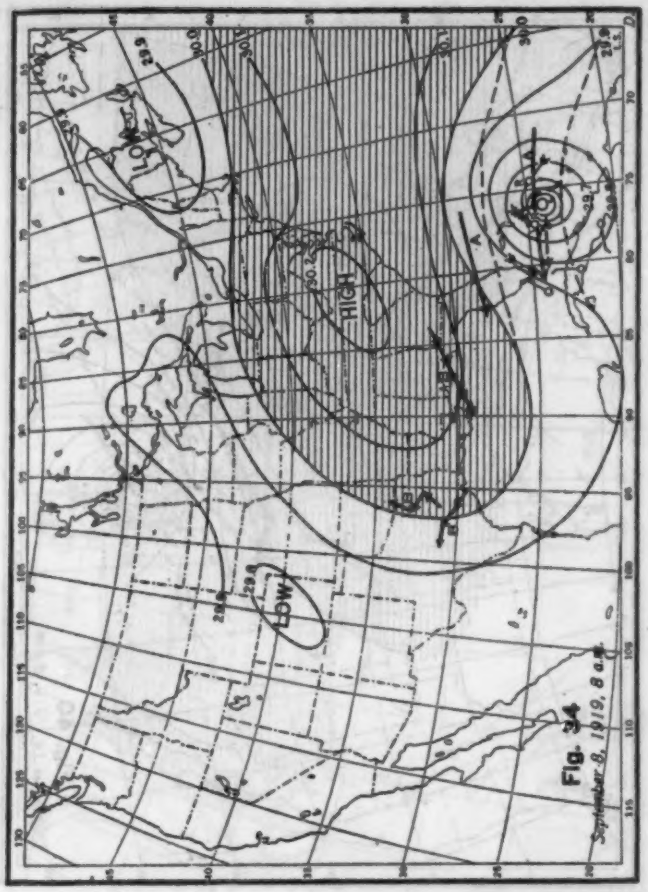


Fig. 34
September 8, 1919, 8 a.m.

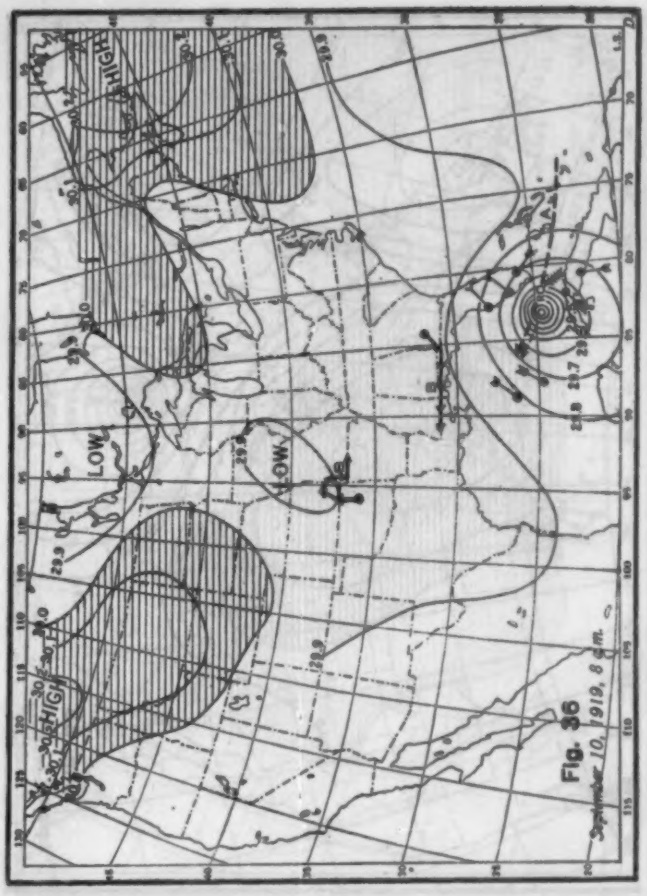


Fig. 36
September 10, 1919, 8 a.m.

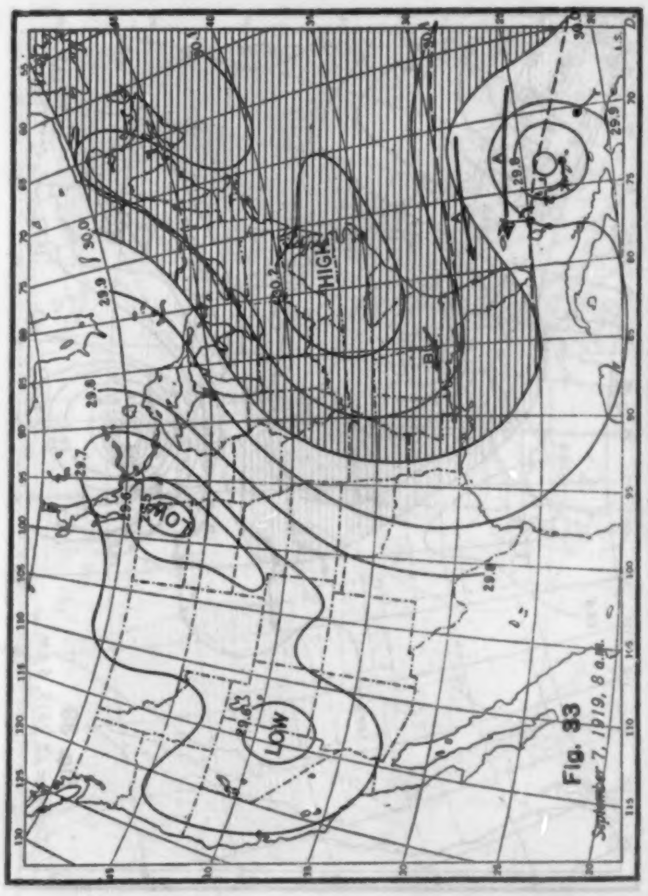


Fig. 33
September 7, 1919, 8 a.m.

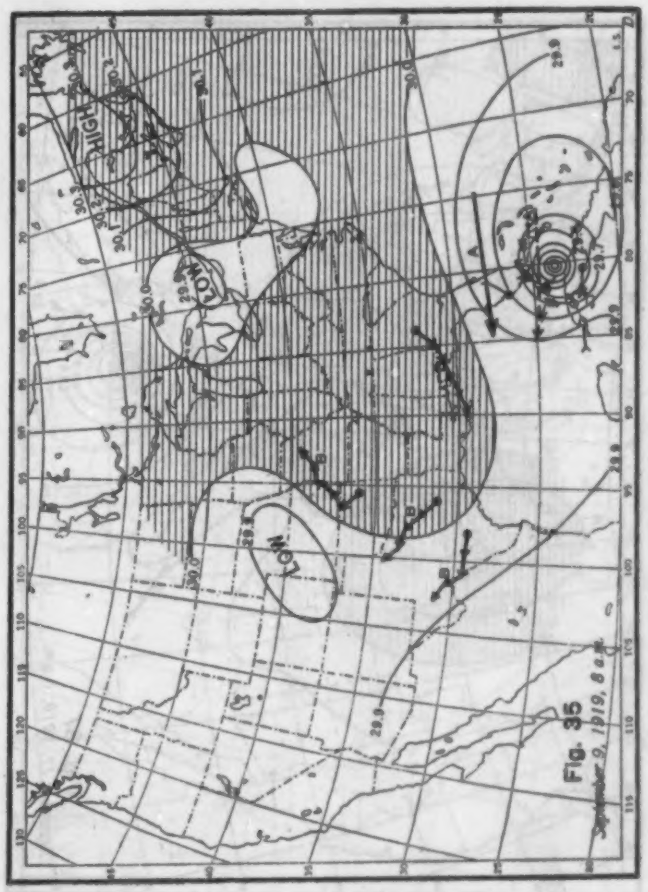


Fig. 35
September 9, 1919, 8 a.m.

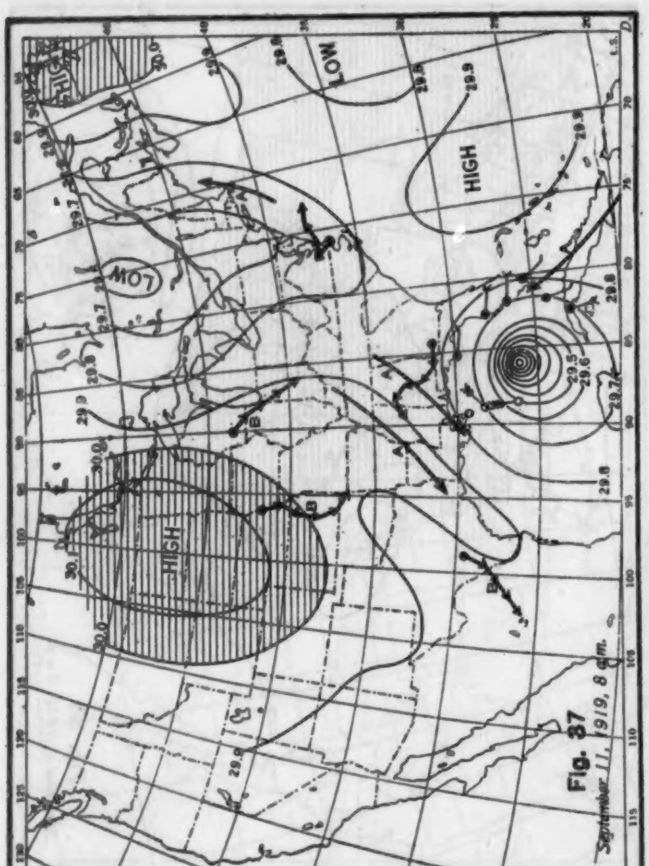


Fig. 37
September 11, 1919, 8 a.m.

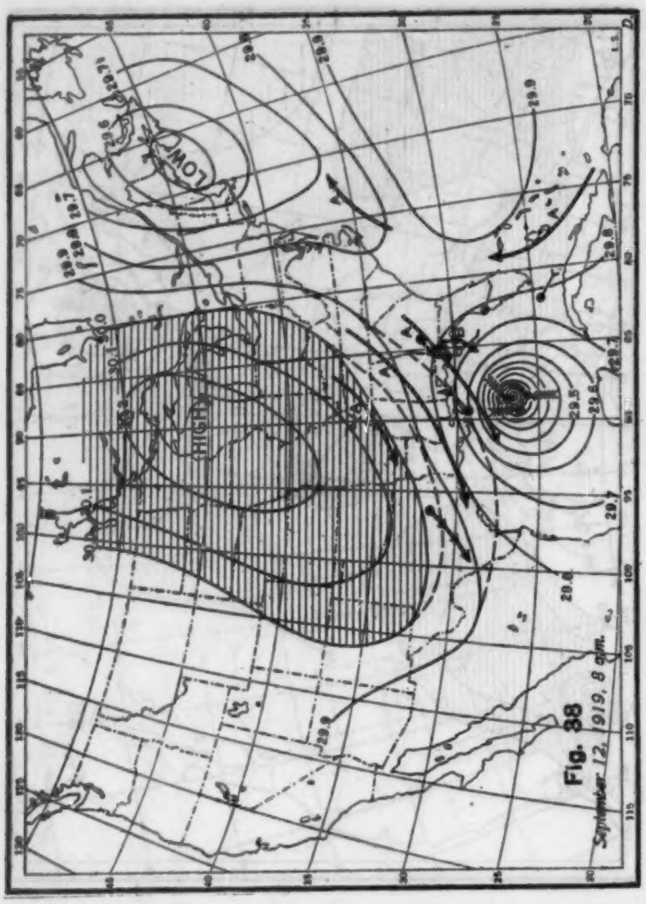


Fig. 38
September 12, 1919, 8 a.m.

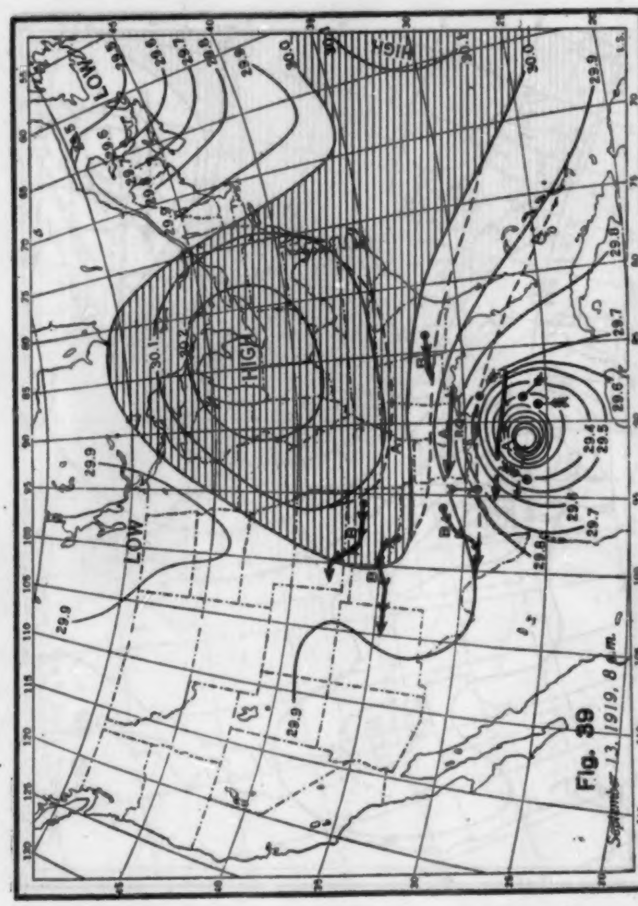


Fig. 39
September 13, 1919, 8 a.m.

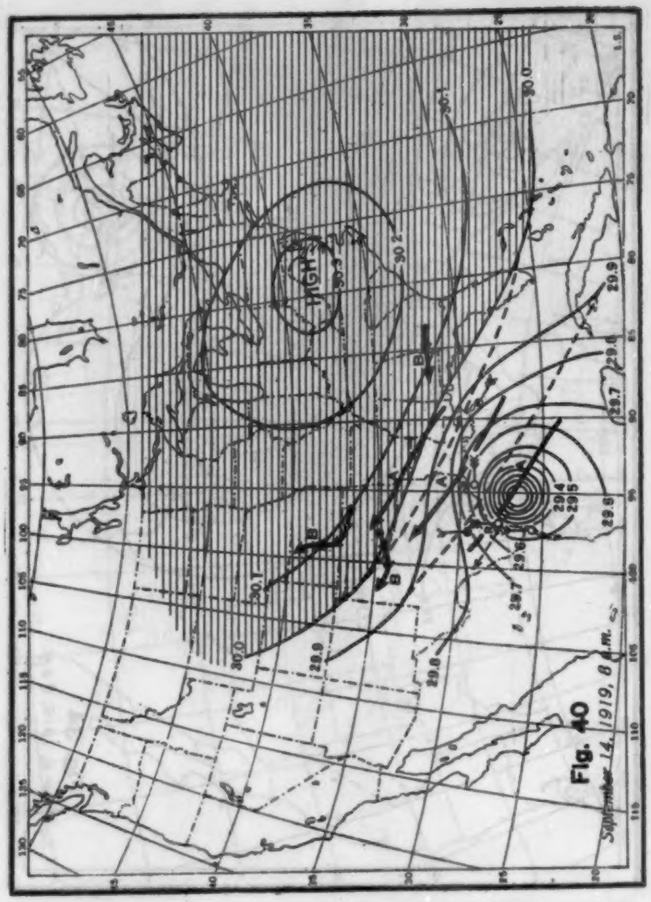


Fig. 40
September 14, 1919, 8 a.m.

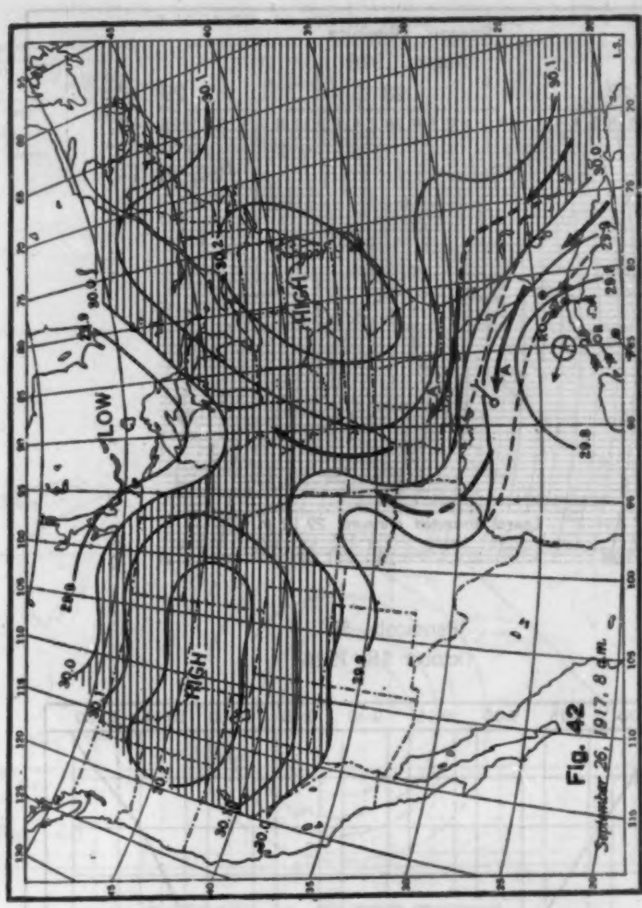


Fig. 42
September 26, 1917, 8 a.m.

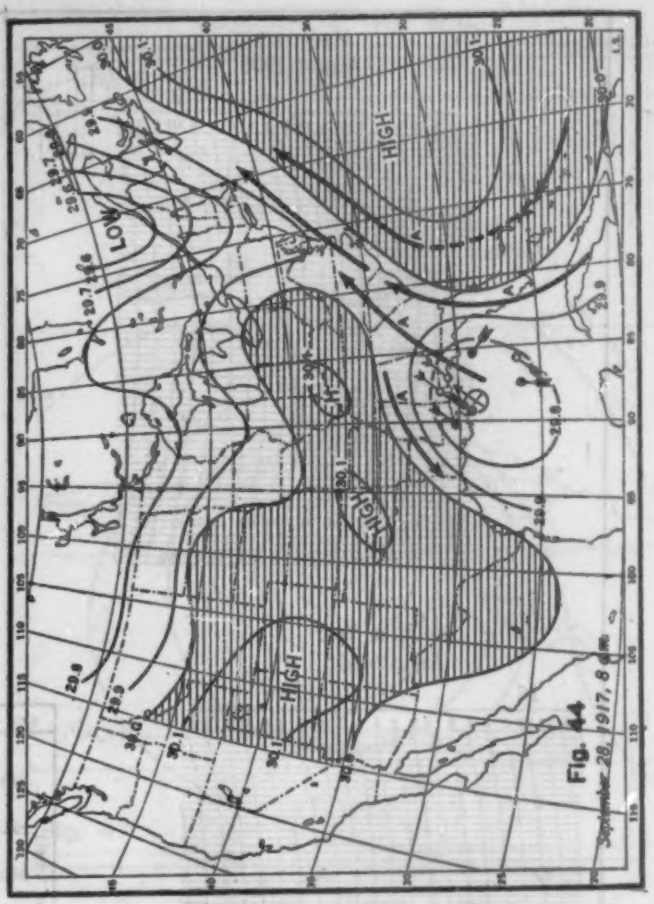


Fig. 44
September 28, 1917, 8 a.m.

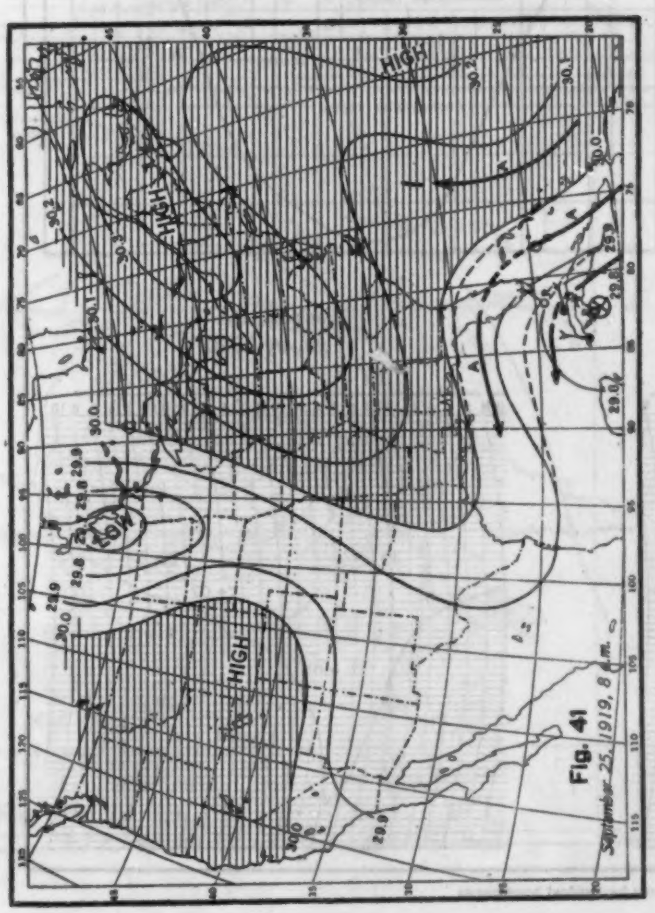


Fig. 41
September 25, 1919, 8 a.m.

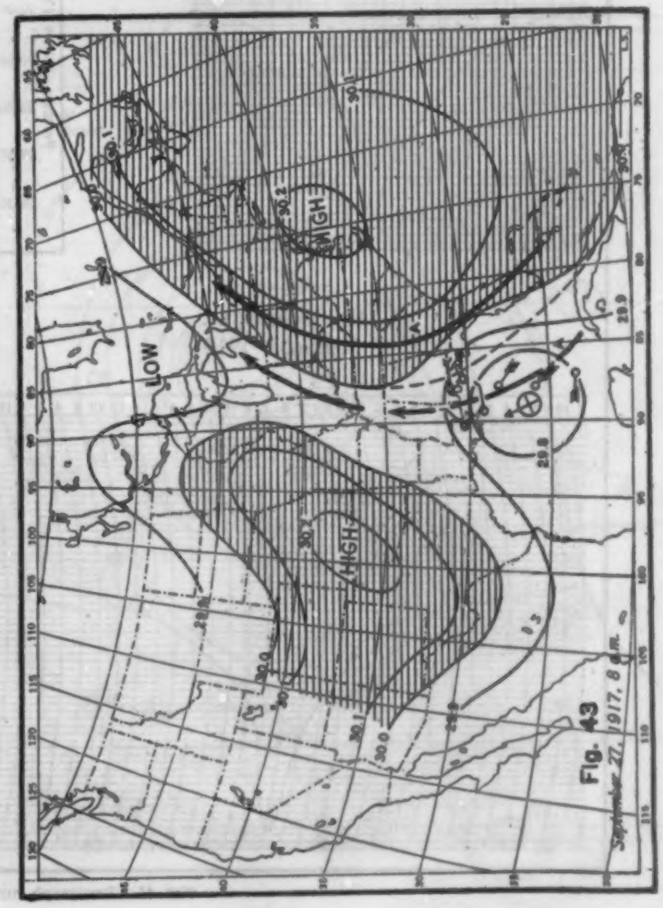


Fig. 43
September 27, 1917, 8 a.m.

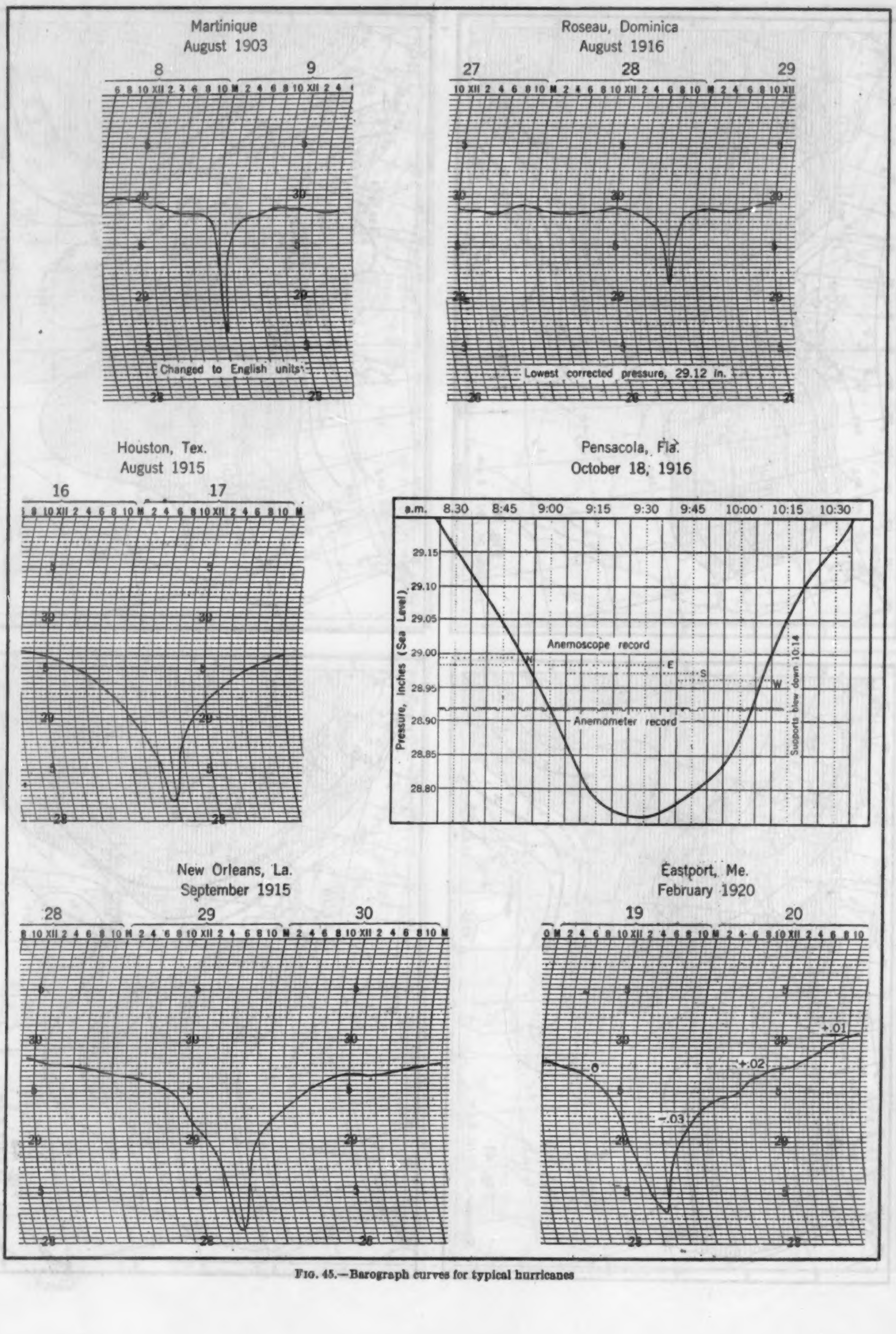
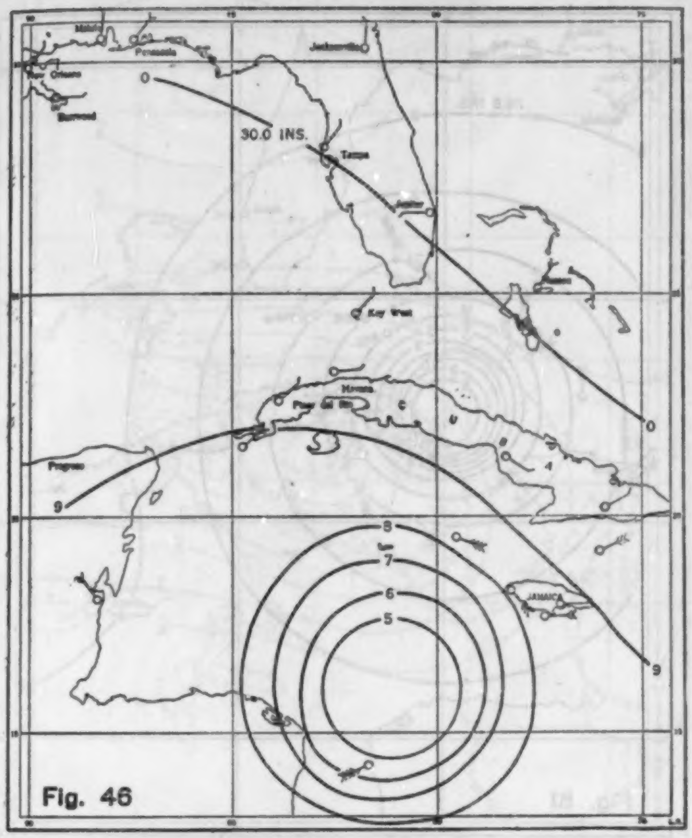


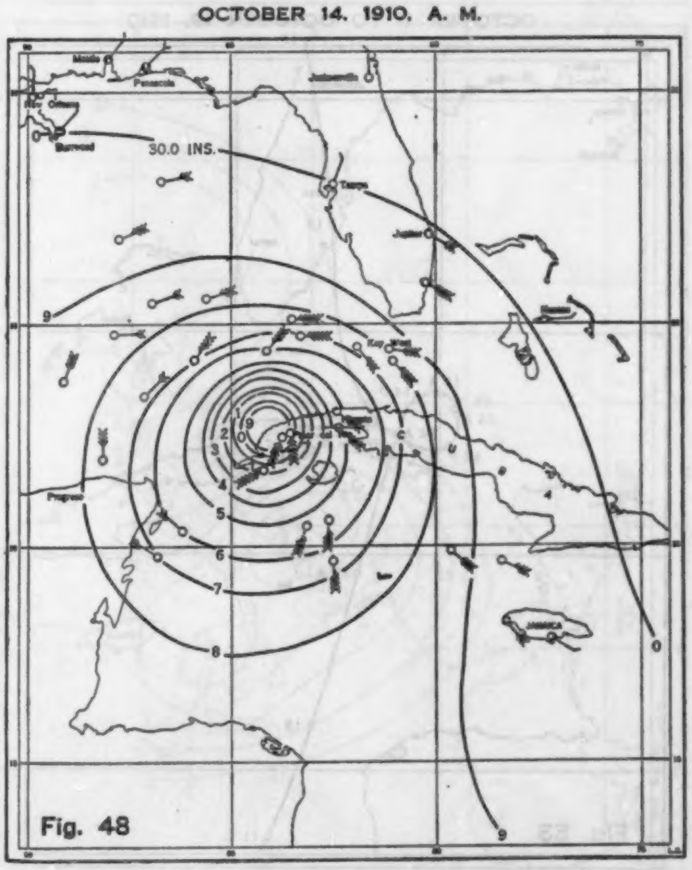
FIG. 45.—Barograph curves for typical hurricanes

OCTOBER 12, 1910, A. M.

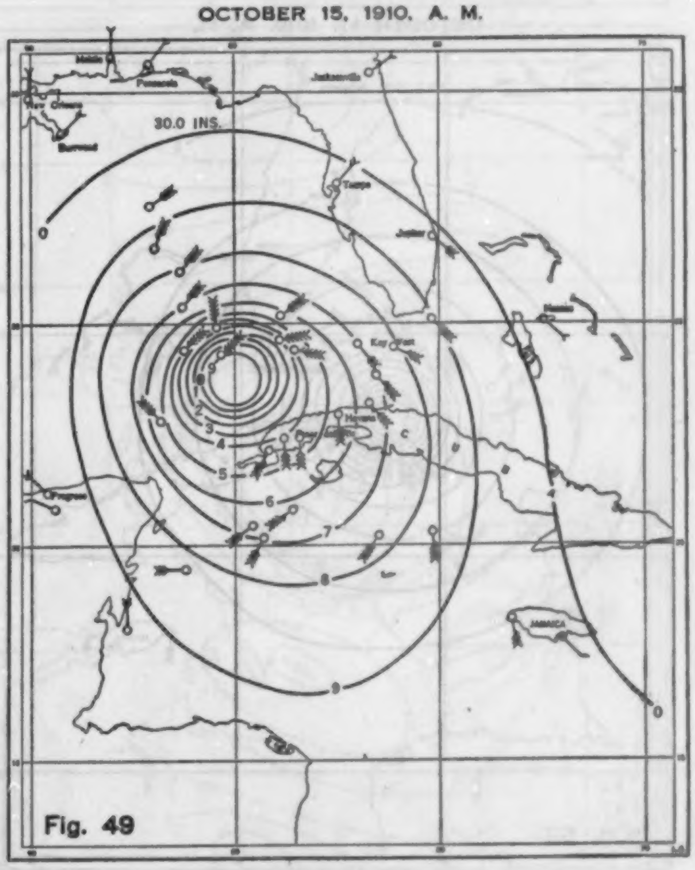


OCTOBER 13, 1910, A. M.

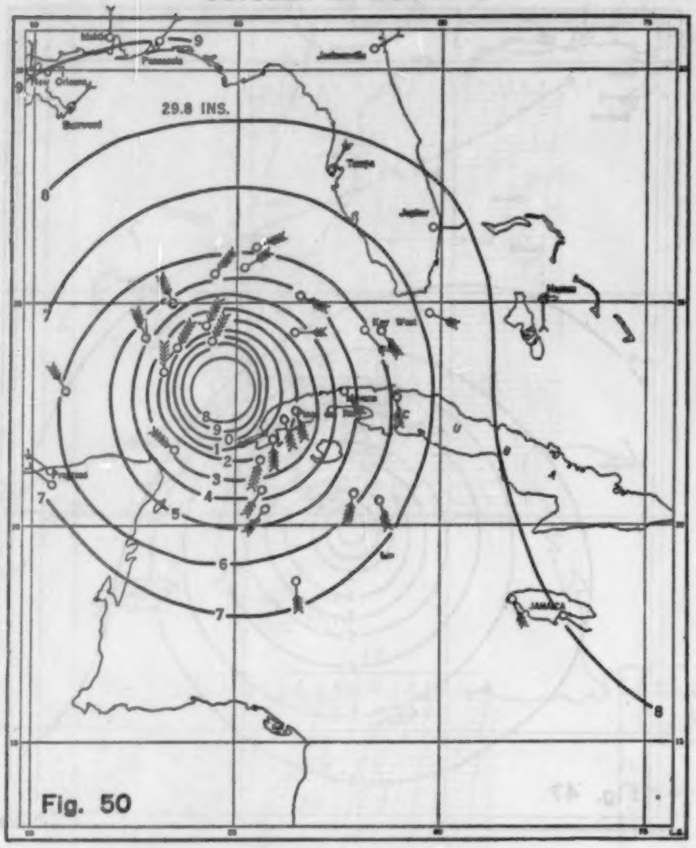
OCTOBER 14, 1910, A. M.



OCTOBER 15, 1910, A. M.

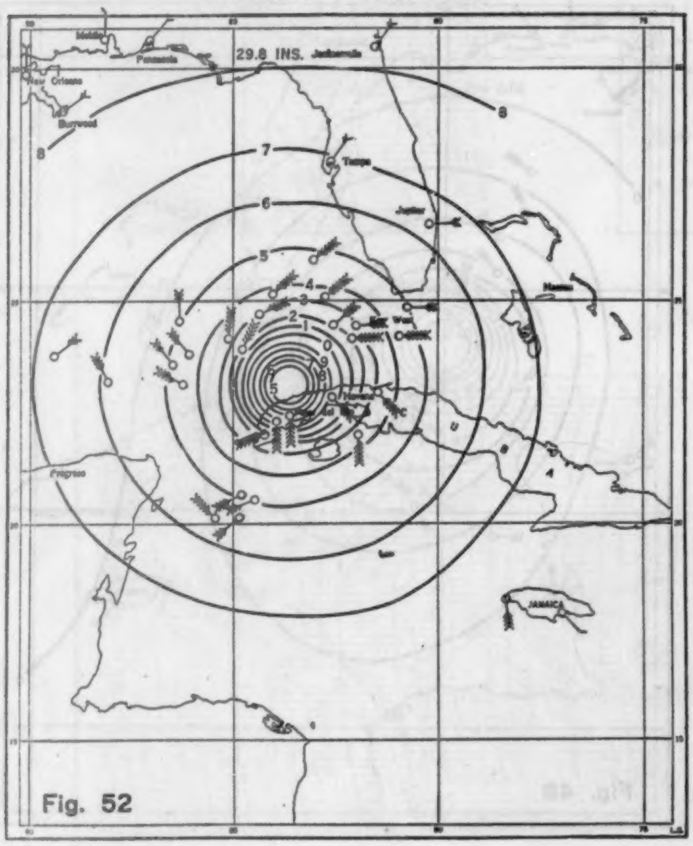


OCTOBER 16, 1910, A. M.



OCTOBER 16, 1910, P. M.

OCTOBER 17, 1910, A. M.



OCTOBER 11 TO OCTOBER 19, 1910

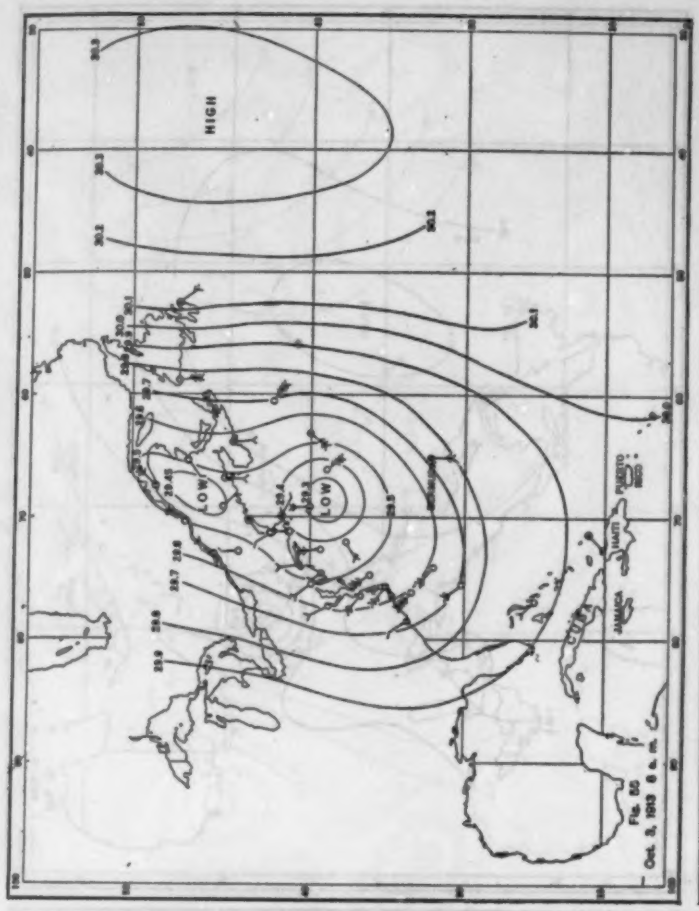


Fig. 55 Oct. 3, 1913 8 a.m.

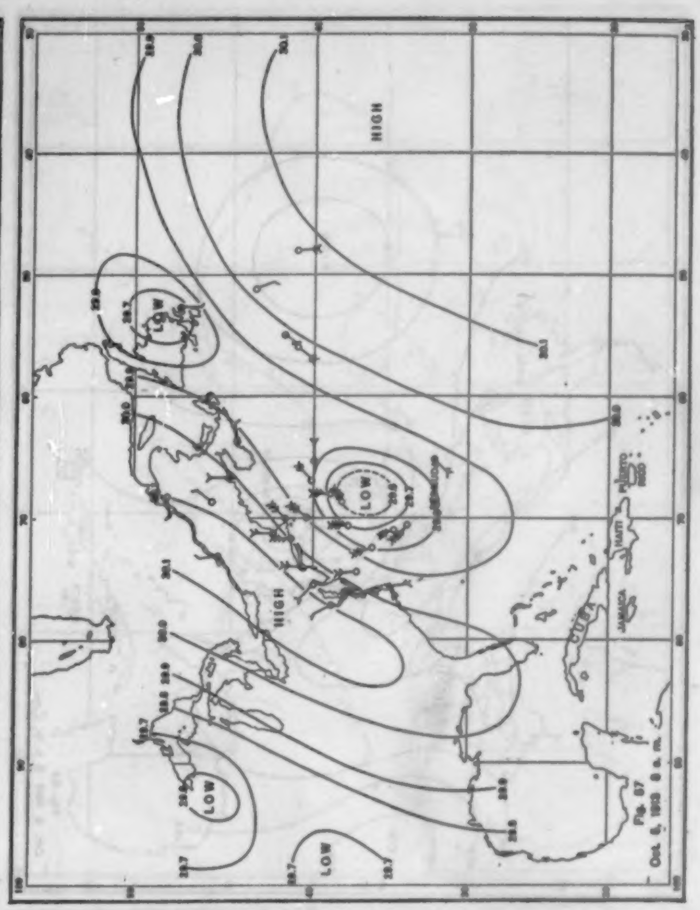


Fig. 57 Oct. 5, 1913 8 a.m.

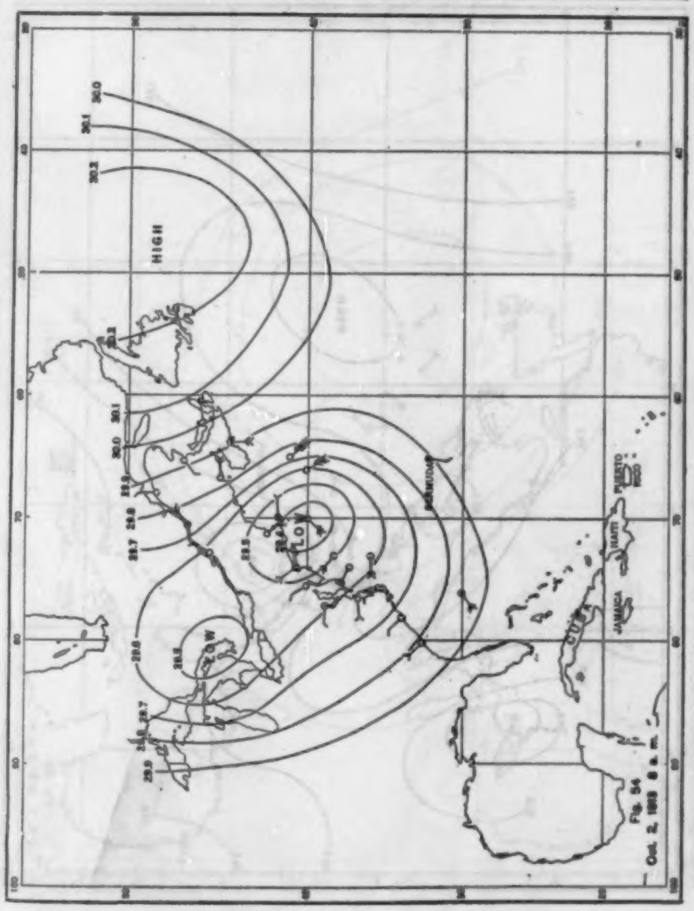


Fig. 54 Oct. 2, 1913 8 a.m.

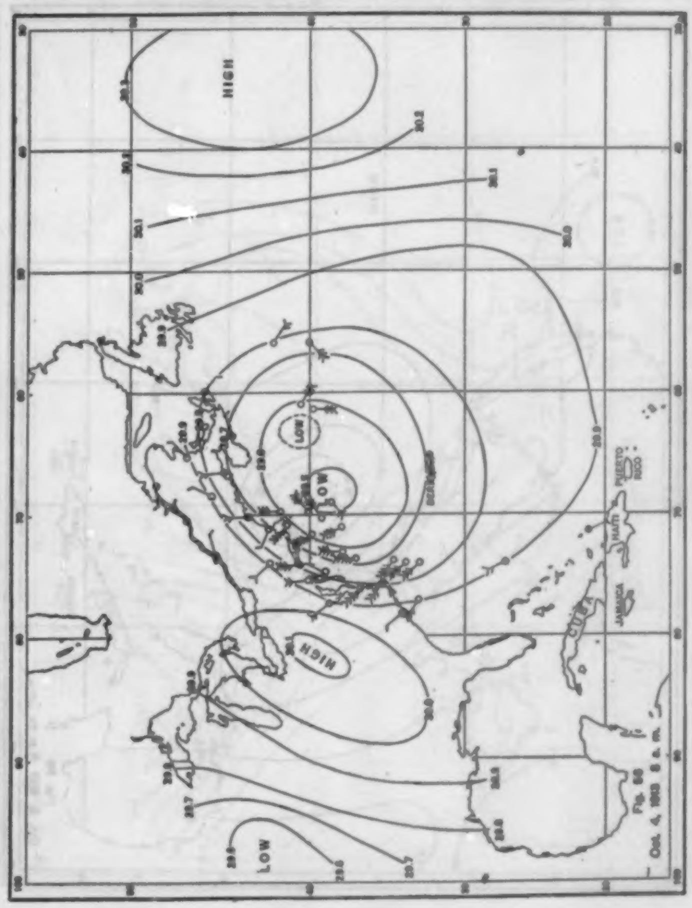


Fig. 56 Oct. 4, 1913 8 a.m.

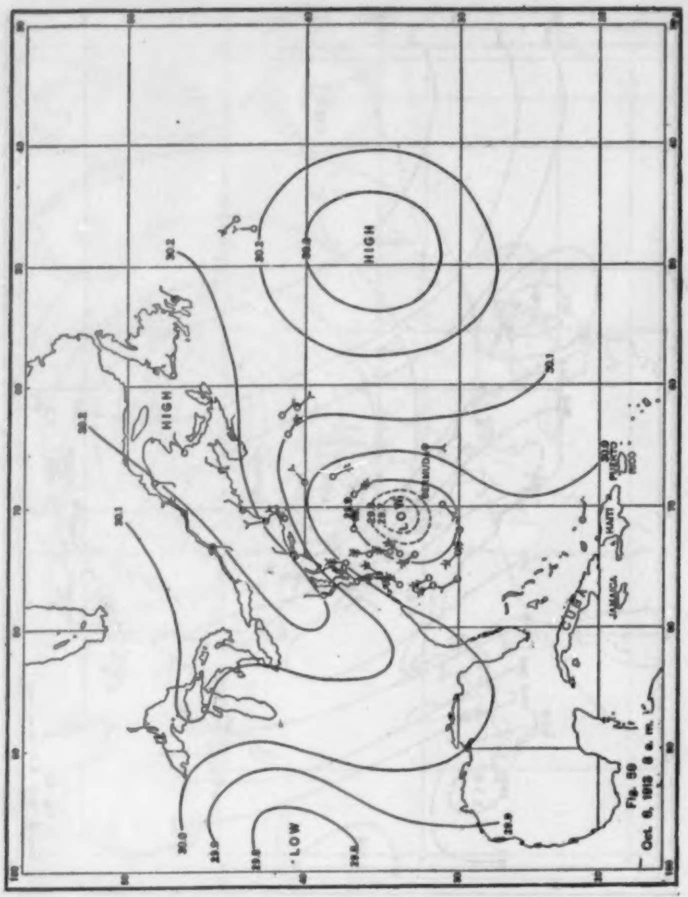


Fig. 59
Oct. 6, 1918 8 a. m.

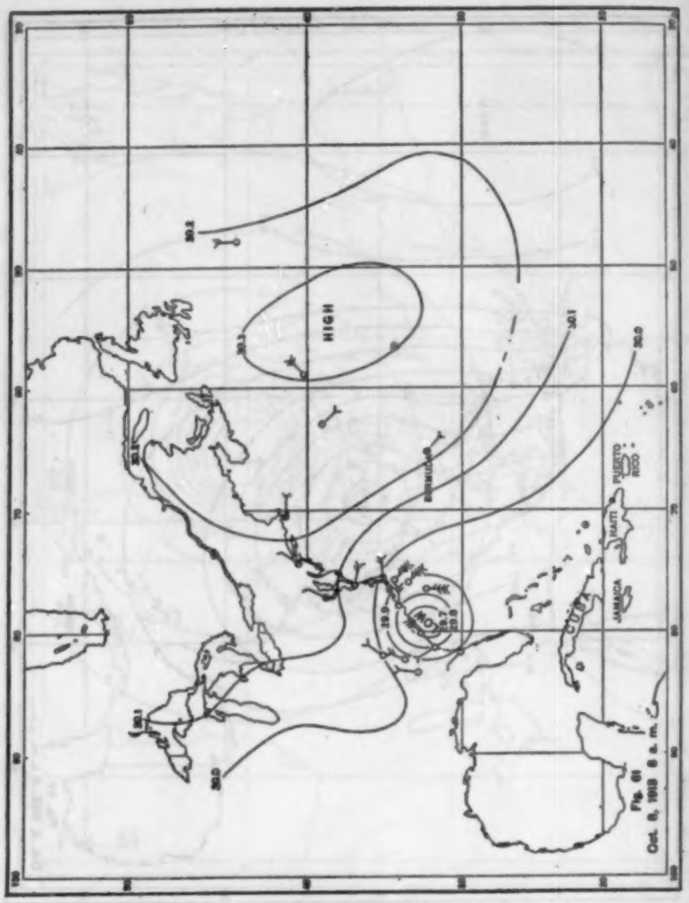


Fig. 61
Oct. 6, 1918 8 a. m.

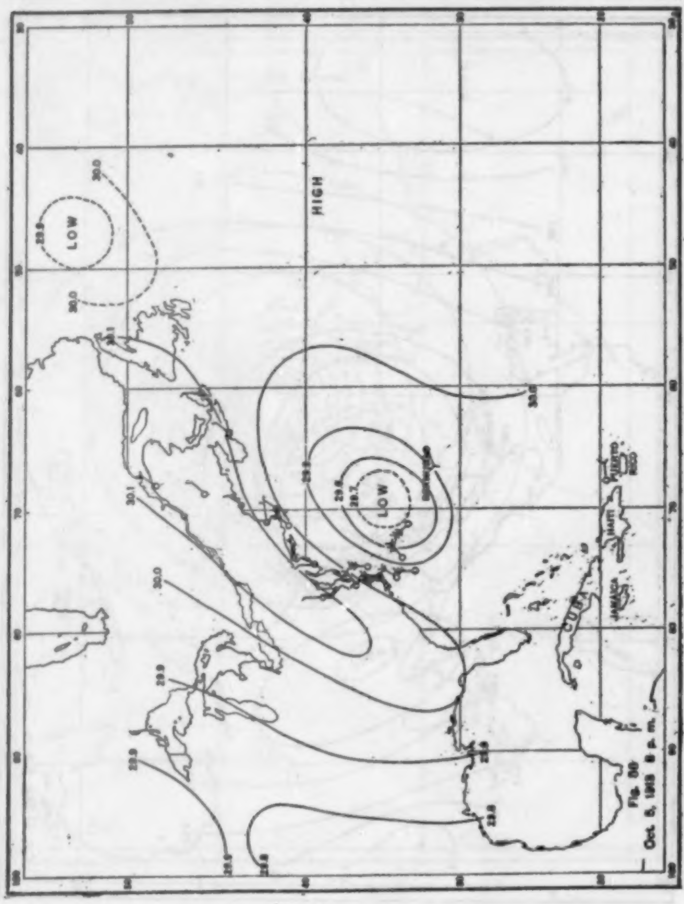


Fig. 60
Oct. 5, 1918 8 p. m.

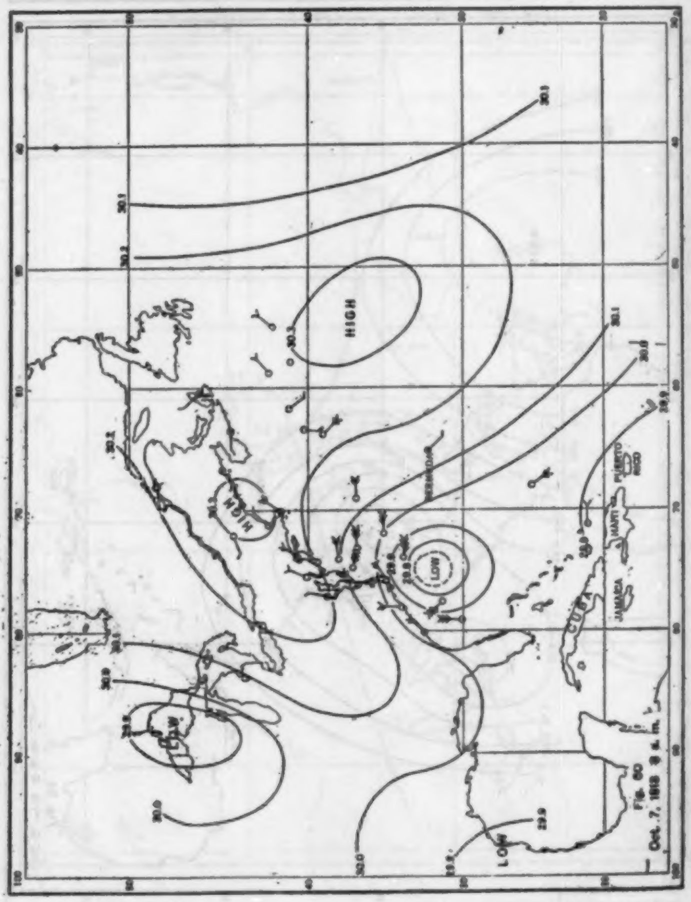


Fig. 60
Oct. 7, 1918 8 a. m.

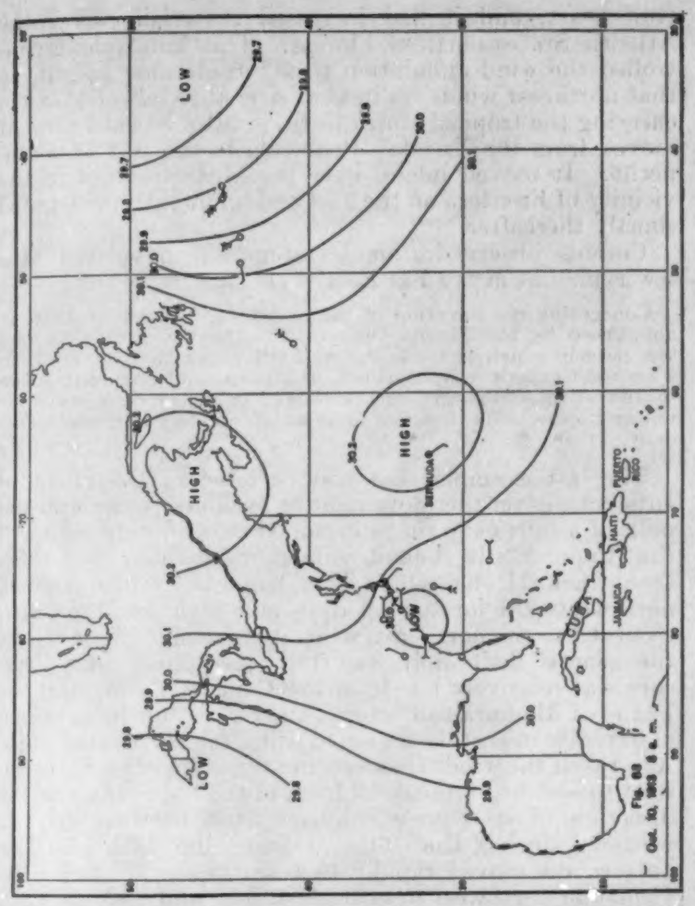


Fig. 63. Oct. 10, 1913 8 a.m.

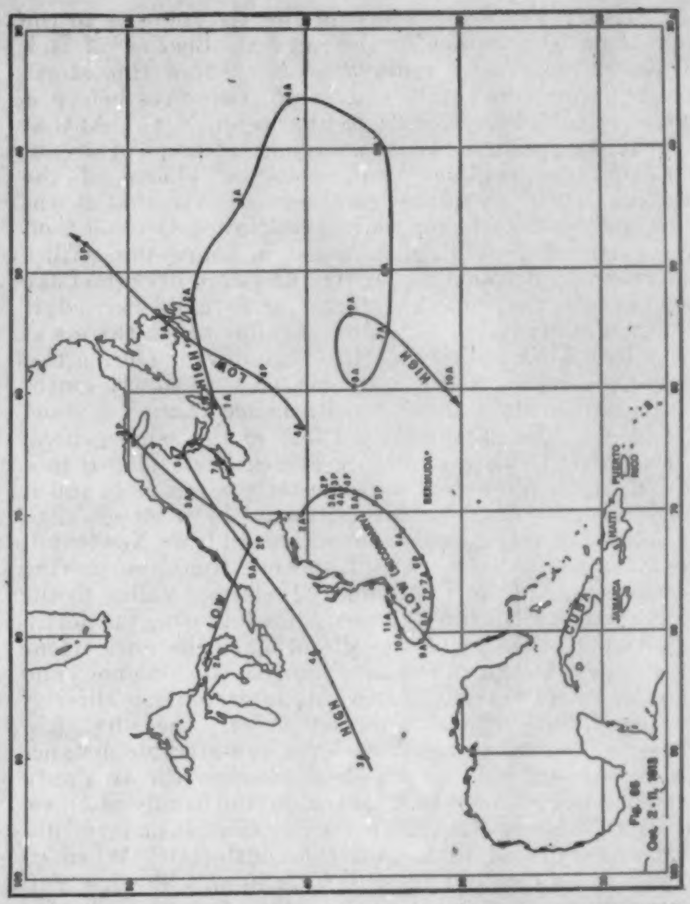


Fig. 65. Oct. 2-11, 1913

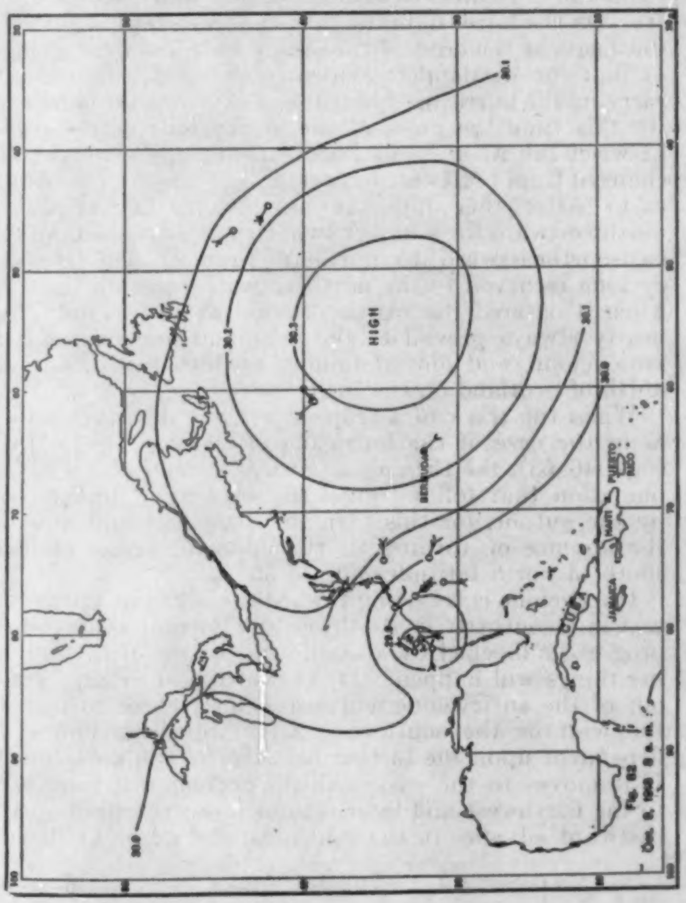


Fig. 62. Oct. 9, 1913 8 a.m.

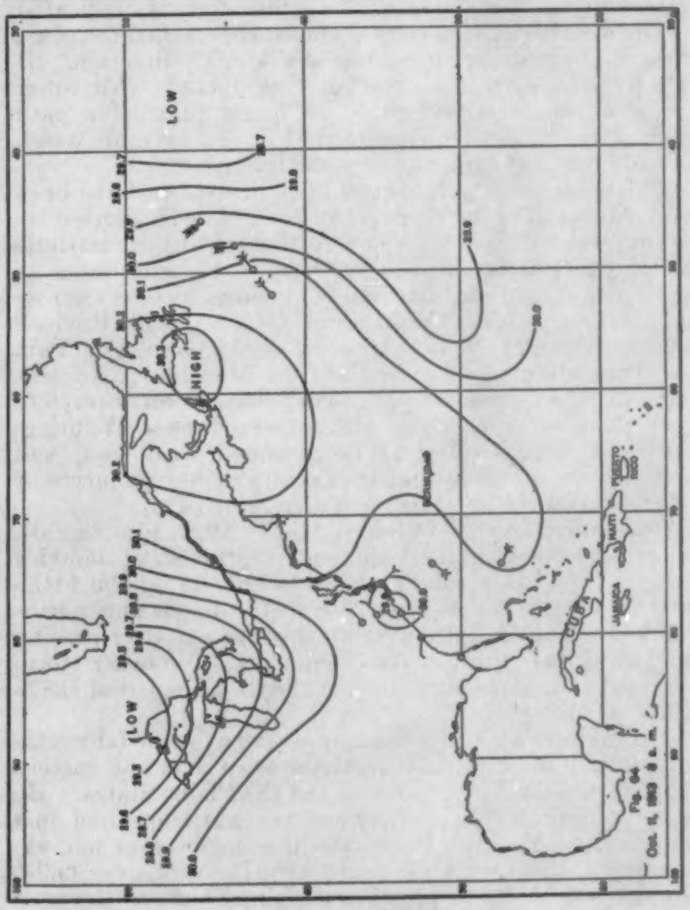


Fig. 64. Oct. 11, 1913 8 a.m.

moved southwestward, which is directly opposite to the normal path of storms in this region. Because of lack of vessel reports by radio the presence of this storm was not discovered until October 6, two days before it moved inland in the vicinity of Charleston, S. C. At that time it was thought to be a cyclone of tropical origin; however, the complete meteorological charts of the North Atlantic Ocean showed otherwise—viz, that it was a secondary disturbance that developed on October 2 off the southern New England coast in connection with a barometric depression that moved eastward over the Lake region, and that northwesterly winds aloft carried it slowly southeastward for 24 hours, after which there was very little wind velocity aloft for two days. During this period the center of the storm moved very slowly southward. Meanwhile another disturbance formed a short distance to the northeastward but in the same general storm area. This disturbance evidently developed in a region where there were southwesterly winds aloft and it therefore moved off to the northeast between an anticyclone that was moving southeastward from Newfoundland toward the Azores and another that was moving northeastward from the middle Mississippi Valley to the North Atlantic States. Immediately following the northeastward movement of this disturbance the anticyclone over the Atlantic Ocean changed its course and started to move southwestward, later moving directly westward for several hundred miles. (See fig. 65.) Pressure gradually increased for a considerable distance above the surface over the area between the two anticyclones (which merged), and soon the winds aloft set in from the northeast, carrying the secondary disturbance referred to toward the southwest. When its center was almost due east of Charleston, the wind aloft shifted to easterly and later to southeasterly, as indicated by the weather charts, so that the storm reached the coast line while moving in a northwesterly direction. It rapidly lost intensity after moving inland. No other storm of which record could be found pursued a path that even remotely resembled that of this cyclone, which at times reached almost hurricane intensity.

The details of the movements of this storm have been thus emphasized because the storm has been plotted as having moved very rapidly northeastward to latitude 46° N., longitude 44° W., by October 11, and later as having pursued an extremely devious course across the Atlantic. (See McAdie in Geographical Review, **10**: 39-39, and Shaw, Manual of Meteorology, Part IV, frontpiece, with reference to McAdie.) According to the writer's judgment, based on complete data of the storm, it was still centered near Wilmington, N. C., on October 11, very much weakened, and a progress northeastward was impossible on account of the extensive anticyclone above referred to.

The hurricane of October 14-21, 1922 (see fig. 6), which developed a short distance southwest of Jamaica and moved slowly west-northwestward during the 14th-18th, not only did not recurve to the north and northeast, but it actually moved southwestward after passing westward over the Yucatan Peninsula. No other storm pursued a similar course during the 37-year period 1887-1923, inclusive.

On the 15th an anticyclone appeared over the far northwest and moved rapidly southeastward over the eastern slope of the Rocky Mountains and the Plains States. By the morning of the 18th, when the hurricane had just reached the Yucatan Peninsula, this anticyclone had extended to the west Gulf coast with its crest over Oklahoma. On the 19th pressure remained high to the west Gulf coast, and it had increased materially over the Atlantic States north of Florida. This anticyclone controlled the wind circulation to a considerable height, so that northeast winds set in aloft over the Gulf of Mexico, carrying the tropical storm to the southwestward after it moved from the Yucatan Peninsula to the Bay of Campeche. It moved inland over the Mexican coast in the vicinity of Frontera on the 21st and apparently dissipated shortly thereafter.

Coronas observed a similar abnormal movement of a few typhoons in the Far East. He says: [16]

> Concerning the direction of the Christmas typhoon of 1918, as announced by the Manila Observatory, the writer remembers a few cases in which he found it very hard to persuade some otherwise well experienced mariners that typhoons inclining west-southwest or southwest, whether inland or in the open sea, were not an impossibility, but real facts which no one could reasonably deny. * * *

The last example that will be cited of the effect of anticyclones on the movement of cyclones is the unusual path of a hurricane that developed immediately south of the Cape Verde Islands about September 9, 1900. (See track II, fig. 66.) This tropical cyclone moved northwestward for several days and then (on the 13th) recurved to the northeast, when it reached a region where the general drift aloft was from the southwest. Pressure was relatively low from the Canary Islands and the Island of Madeira to Portugal and Spain, but it increased materially over this region during the 15th and 16th. As a result the winds aloft apparently changed from southwest to east or southeast in front of the hurricane and the direction of its course changed from northeasterly to westerly during the 16th. During the 13th-17th an anticyclone moved rapidly east-southeastward from the Canadian northwest to latitude 40° N. and longitude 40° W. On the latter date the hurricane was central directly southeast of the crest of the anticyclone and near enough so that the winds aloft evidently changed to northeast, carrying the hurricane toward the southwest for two days. By this time the crest of the anticyclone was midway between the Azores and Portugal, and the general drift changed from northeast to east, and by the 20th to southeast. After this date the anticyclone moved slowly northwestward for a day or two, then it advanced rapidly east-northeastward to northern France. The tropical cyclone recurved to the northeastward early on the 22d, when it entered the region of southwesterly winds that nearly always prevail to the west and northwest of an anticyclone, and moved rapidly northeastward, passing north of Scotland on the 24th.

When the track of a tropical cyclone describes a loop as in the case of the hurricane of October 12-21, 1910 (figs. 46-53), the turning is always *to the left*. The explanation that follows gives the reasons, as understood by the author, for this turning to the left and also for the absence of turning in the opposite sense, at least south of north latitudes 30° to 35°.

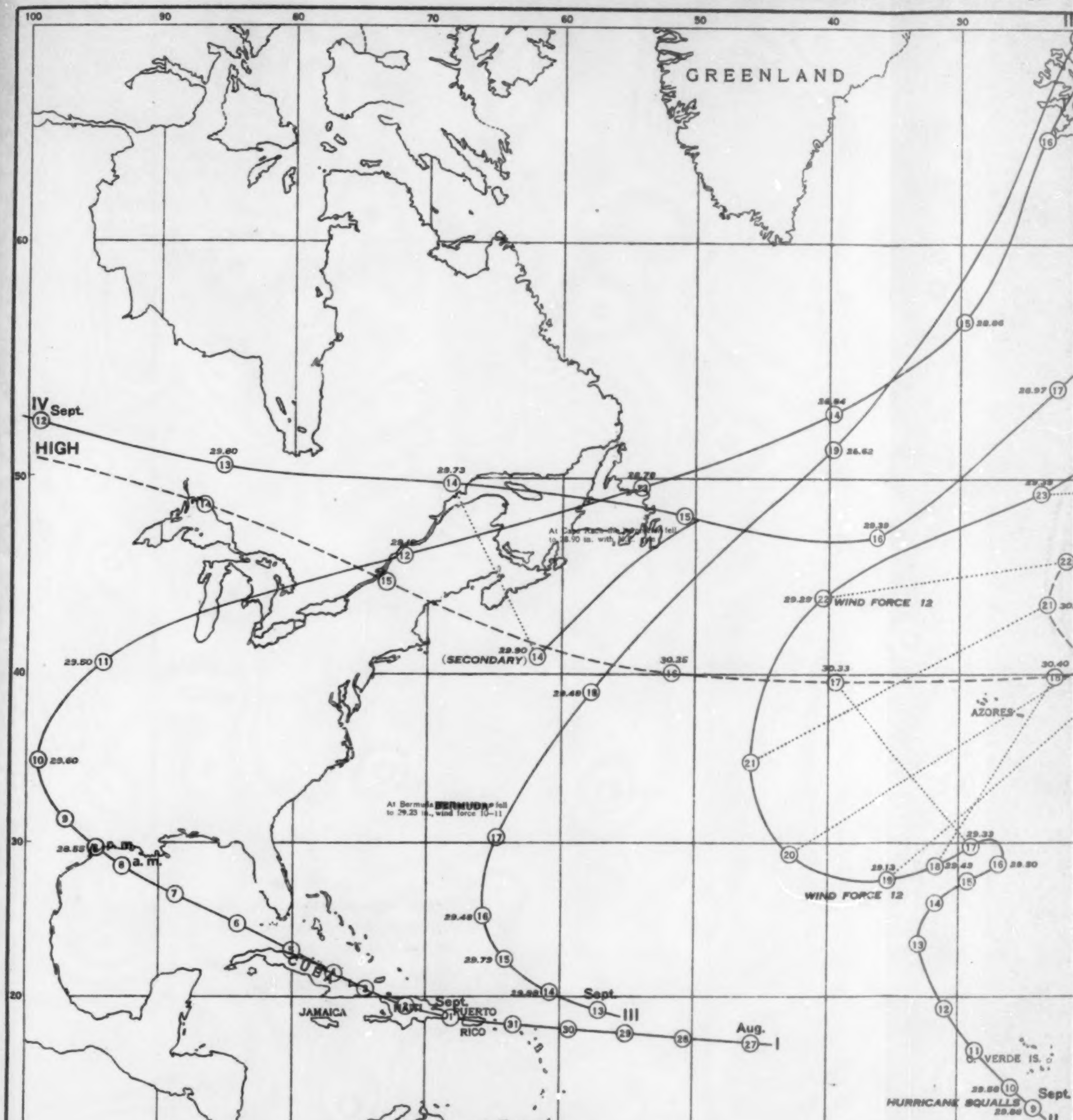
If a cyclone is traveling toward the north or the northeast in a southerly or southwesterly current aloft and its progress is blocked by an anticyclone, one of the following things will happen: (1) The northeast or east winds out of the anticyclone will cause the cyclone to turn to the west or the southwest, after which its course is dependent upon the further behavior of the anticyclone. If it moves to the eastward, the cyclone will soon turn to the northwest and later resume its interrupted northeastward advance in the southwesterly winds aloft west

[16] Rev. José Coronas, S. J.: The "Quantico" typhoon, *Nature*, London, Sept. 25, 1919, p. 79.

CORRECTION

The months named in titles of Figs. 66 and 66a should be exchanged; Fig. 66 refers to September, 1900, and 66a to August, 1893.

Fig. 66. Tracks of Four Hurricanes in Progress Simultaneously, Aug



ss Simultaneously, August, 1893

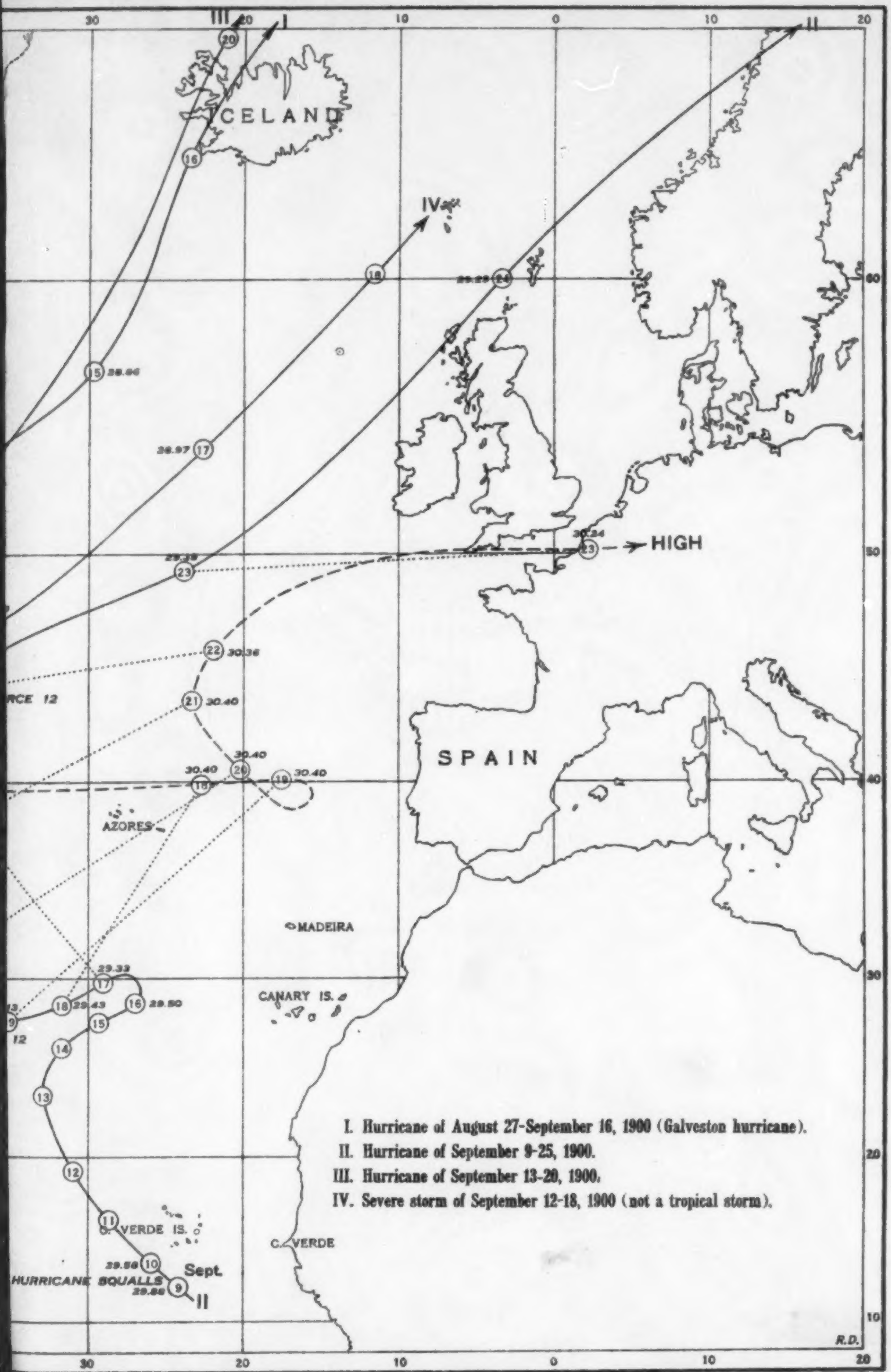
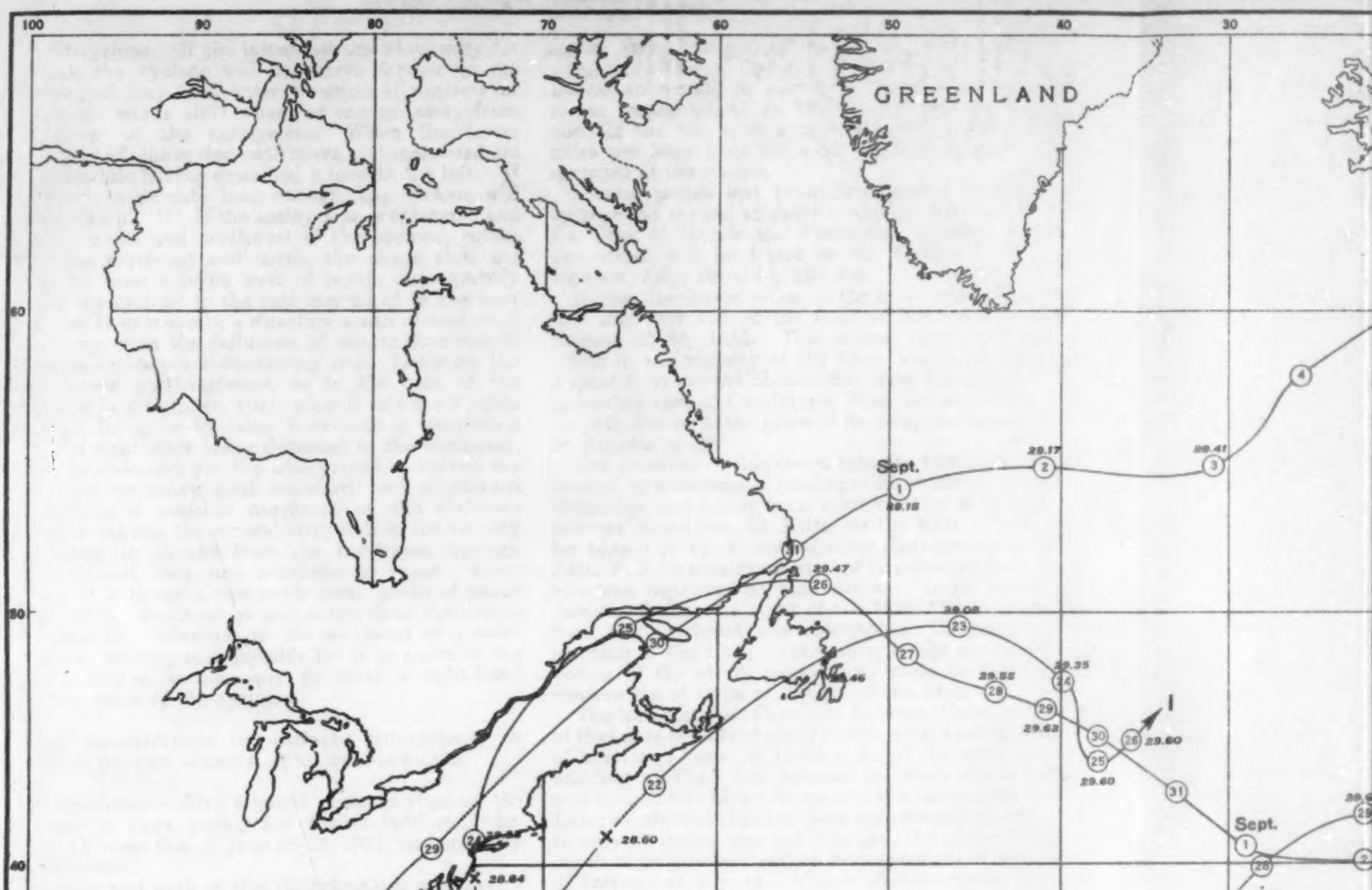
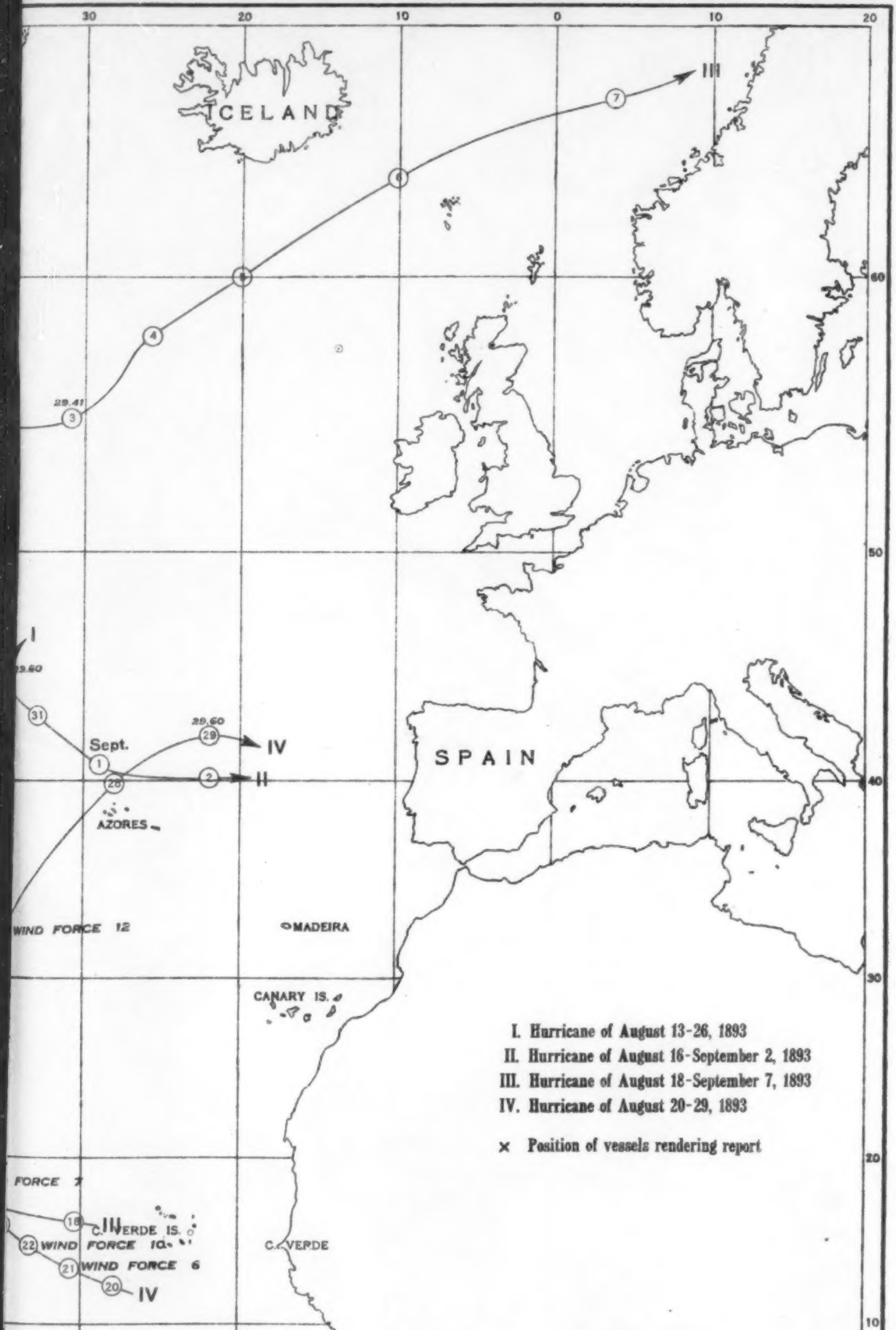


Fig. 66a. Tracks of Three Hurricanes and One Extra Tropical Cyclone Existing at the



lone Existing at the Same Time, September, 1900



of the anticyclone. If the latter remains stationary for some time, the cyclone will be driven farther to the southwest and may then enter a region of westerly or southwesterly winds aloft when far enough away from the influence of the anticyclone. When the latter finally moves off, the cyclone will move northeastward, its track meanwhile having described a loop to the left. If the anticyclone persists long enough, the cyclone will gradually fill up. (2) If the anticyclone is extensive and lies to the north and northwest of the cyclone, rather than to the northeast and north, the winds aloft are likely to be from a point west of north, consequently deflecting the cyclone to the east instead of to the west and causing it to move in a direction south of east until it gets away from the influence of the anticyclone of the type described—a slow-moving one. Later on the cyclone moves northeastward, as in the case of the hurricane of late October, 1921, after it left the Florida peninsula. In order to cause a cyclone to complete a loop to the right after being deflected to the southeast, it would be necessary for the anticyclone to outrun the cyclone and to move southeastward and southward after reaching a position northeast of the cyclone's center, thus causing the general drift aloft in the vicinity of the latter to change from the northwest through north, northeast, east, and southeast to south. However, this, it is thought, can never occur south of about latitude 30° N., inasmuch as the anticyclone that originally causes the deflection to the southeast is a slow-moving one, making it impossible for it to move in the manner indicated as necessary to cause a right-hand loop in the track of the cyclone.

DETAILED DESCRIPTIONS OF CERTAIN HURRICANES IN EACH OF THE MONTHS, JUNE TO NOVEMBER.

June hurricanes.—Five tropical cyclones reached the Gulf coast in June during the period 1887–1923, inclusive. Of these that of June 15–23, 1921, was probably the most severe.

The origin and path of this disturbance is graphically shown in the set of eight individual charts. (Figs. 67–74.) Information as to its intensity during the early days of its course is lacking. However, a radio report from latitude 26° 30′ N., longitude 95° W., at 10 p. m. of the 21st showed a barometric pressure of 29.28 inches and a wind velocity of 78 miles per hour from the southeast. The storm moved inland in the vicinity of Matagorda Bay about noon of the 22d and continued to move as shown in the last of the series of charts. (Fig. 74.)

The maximum wind velocity on the Texas coast in connection with this storm was 68 miles per hour from the northeast at Corpus Christi, Tex. Further details of this storm will be found in the MONTHLY WEATHER REVIEW, June, 1921, **49**: 364.

July hurricanes.—The most severe July hurricane of the Gulf of Mexico was that of June 29–July 5, 1916, whose track and the daily weather charts for the dates July 2–5 are presented in Figures 75–78. The first evidence of the formation of this storm came from north latitude 11°, west longitude 81°. It moved thence, as shown, steadily northwestward, reaching the Mississippi coast six days later. It did not recurve until central Mississippi was reached on the 7th.

This storm was encountered by the U. S. Coast Guard Cutter *Itaska* on the 3d, about 25 miles south of Cape San Antonio, as a whole gale from the east. At 2 p. m. of the 4th the S. S. *Monterey* experienced a whole gale from the southeast with a barometer reading of 29.40 inches about latitude 22° 43′ N., longitude 85° 58′ W., whereupon Gulf shipping was advised by the Weather Bureau to remain in port until further advices. This storm passed inland at Mobile, Ala., during the afternoon of the 5th, with a recorded wind velocity of 107 miles per hour from the east, the highest velocity ever recorded at the station.

Several people lost their lives, and a property loss aggregating several millions of dollars was sustained by the cities of Mobile and Pensacola. Further details of this storm will be found in the MONTHLY WEATHER REVIEW, July, 1916, **44**: 396–398.

August hurricanes.—One of the most severe hurricanes that has ever visited the Gulf of Mexico was that of August 10–24, 1915. This storm apparently had its origin in the vicinity of the Cape Verde Islands about August 5; it moved thence due west for several days, appearing east of Guadalupe, West Indies, on the 10th; its path thence to the place of its disappearance is shown by Figures 25–32.

The entrance of this storm into the Caribbean was indicated by a barometer reading of 29.46 inches at Roseau, Dominica, and a maximum wind velocity of 45 miles per hour at Basseterre, St. Kitts, on the 10th. As the center passed to the westward some distance south of San Juan, P. R., a maximum wind of 60 miles per hour northeast was registered at that station. In its course past Jamaica during the night of the 12th–13th a whole gale from the southeast was recorded at Kingston on the morning of the 13th. Continuing to the northwest, the vortex of the storm passed very close to the extreme western tip of Cuba at 2 p. m. of the 14th.

The barometer at Cape San Antonio, Cuba, at 9 a. m. of that date registered 29.39 inches, with a northeast wind of hurricane force; at 11:30 a. m. of the same date the building at Cape San Antonio in which the barometer was housed was blown down and the instrument broken. Later an aneroid that had been constructed to read down to only 27 inches was put into use, the observer reporting that the pointer reached the lower limit of the scale—27 inches—at 2 p. m. Means of determining the correctness of that reading are not at hand. The steel wireless tower, the lighthouse, and every house in the village of Cape San Antonio were blown down and the débris scattered for miles.

The storm continued its northwestward movement across the Gulf of Mexico at the rate of about 375 miles a day. Its close approach to the coast was indicated by the Galveston observation of 8 p. m. of the 16th—viz, a barometer reading of 29.10 inches and a northeast wind of 72 miles per hour. The storm passed inland the next day attended by a minimum pressure of 28.63 inches at Galveston and 28.20 inches at Houston. The latter station is about 35 miles inland and almost due north of Galveston. The maximum wind velocity at Galveston was 93 miles per hour east and at Houston 80 miles per hour northeast (estimated).

At Velasco, Tex., about 40 miles southwest of Galveston and about 14 miles southwest of San Luis Pass, where the storm center reached the coast, the barometer read 28.06 inches at 1 a. m. At a point 5 miles northeast of Sandy Point there was a calm lasting 20 minutes. As the time consumed by the storm center in traveling from the coast to the vicinity of Houston, a distance of about 60 miles along the curved path, was very nearly 4 hours, or at the rate of approximately 15 miles an hour, and the diameter of the vortex was 5 miles. Examination of the barogram for Houston (fig. 45) shows that that station was under the influence of the storm at least 36 hours.

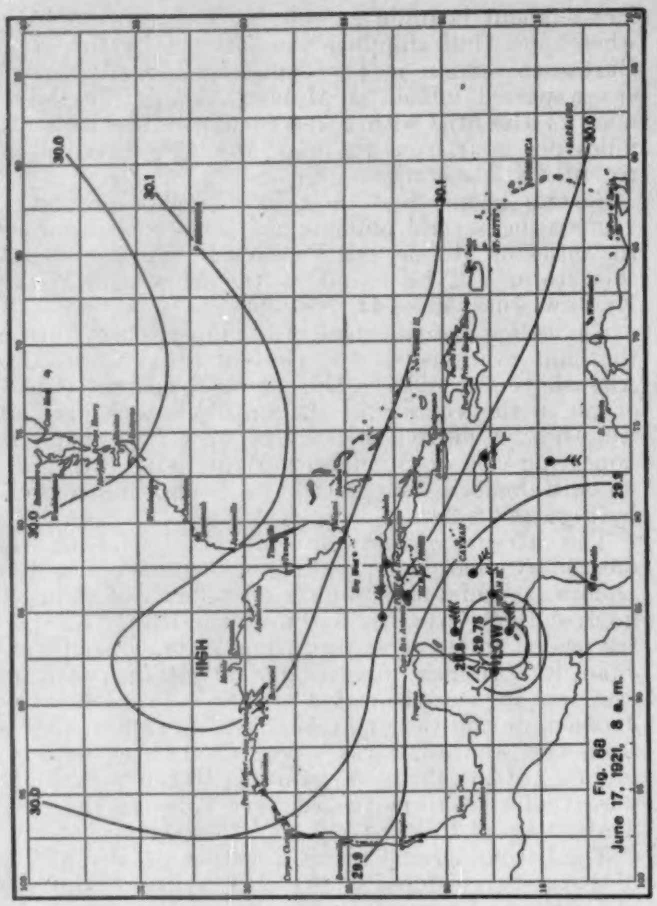


Fig. 68
June 17, 1921, 8 a.m.

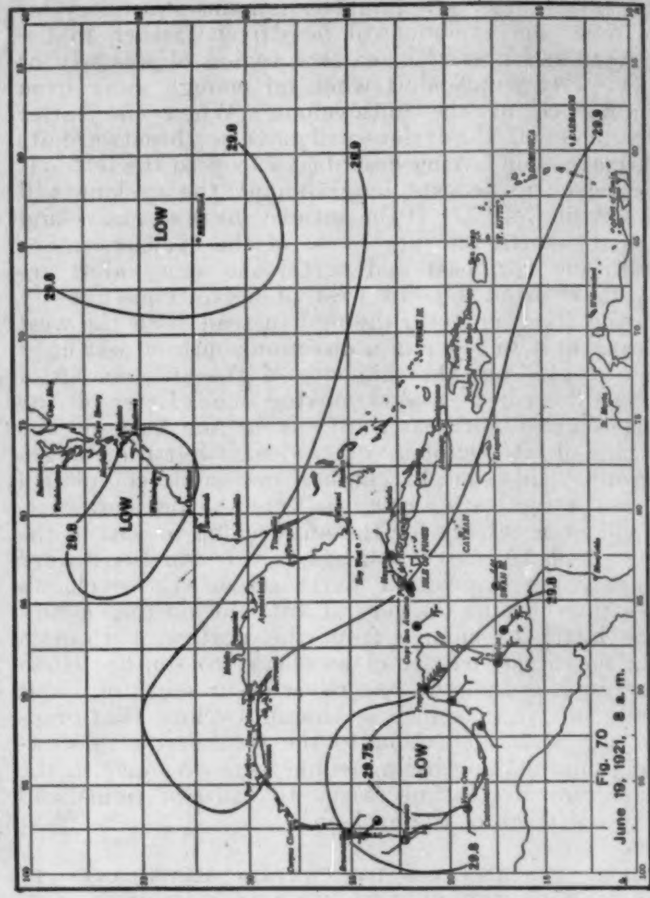


Fig. 70
June 19, 1921, 8 a.m.

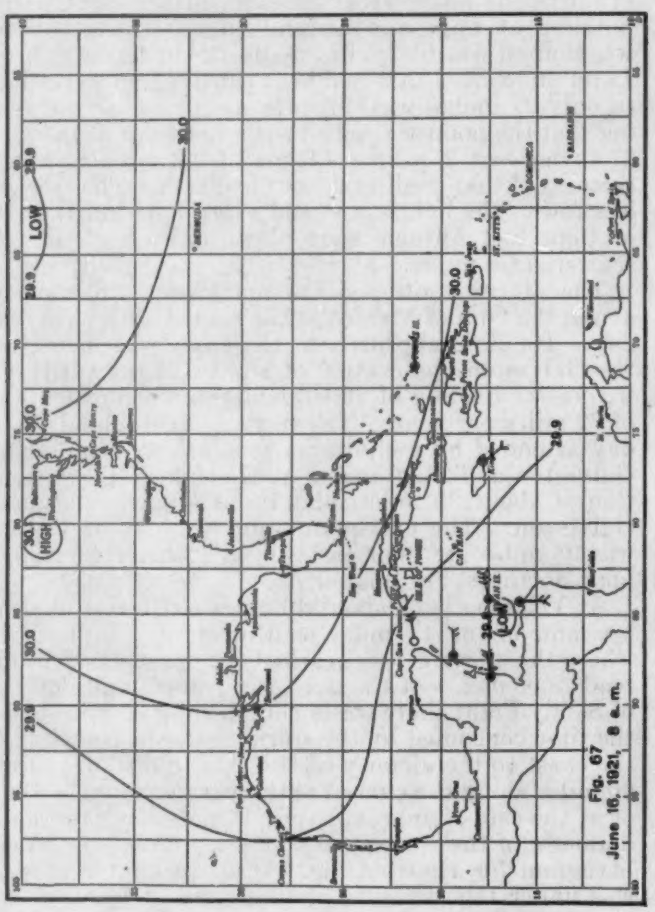


Fig. 67
June 16, 1921, 8 a.m.

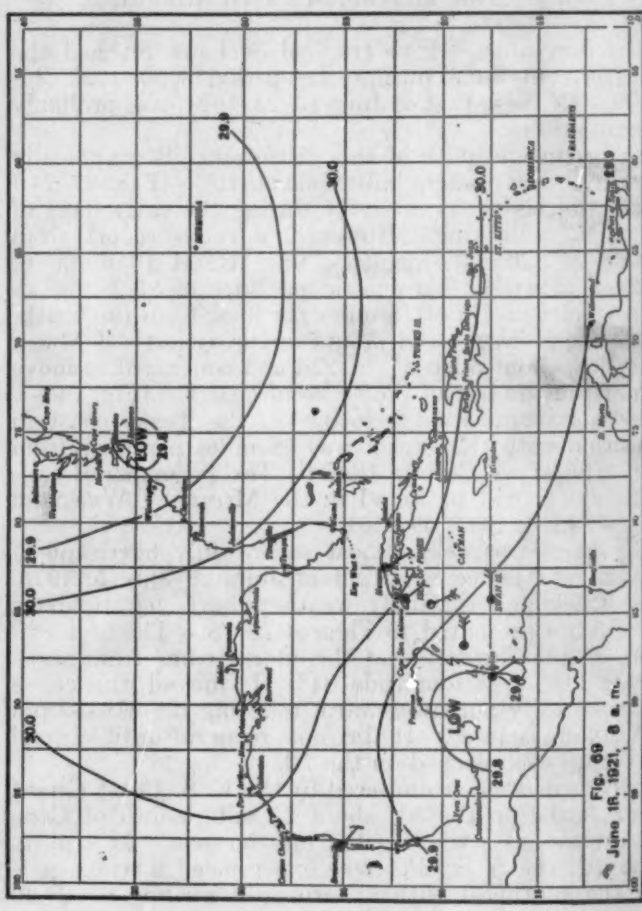


Fig. 69
June 18, 1921, 8 a.m.

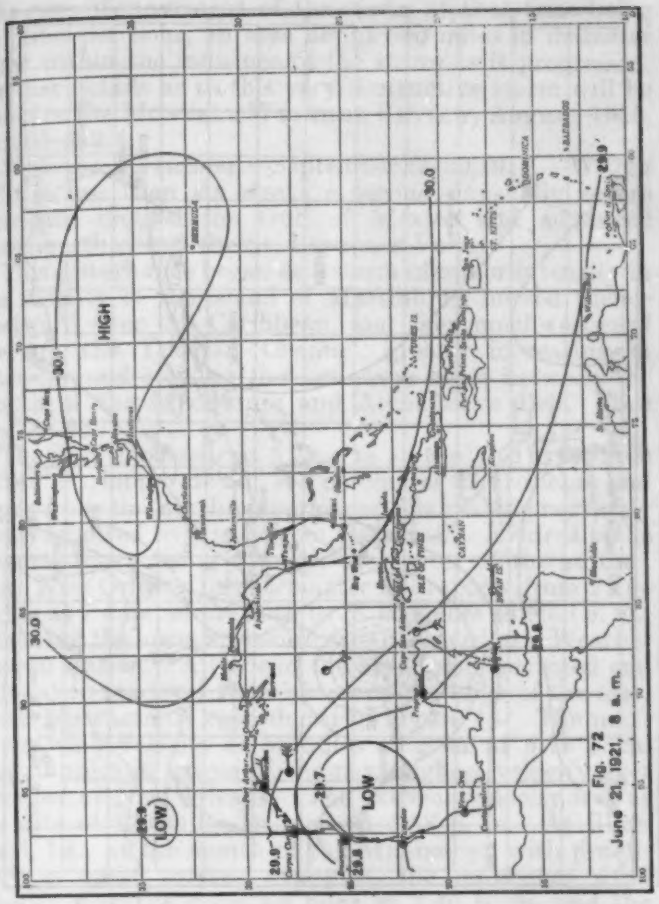


Fig. 72
June 21, 1921, 8 a.m.

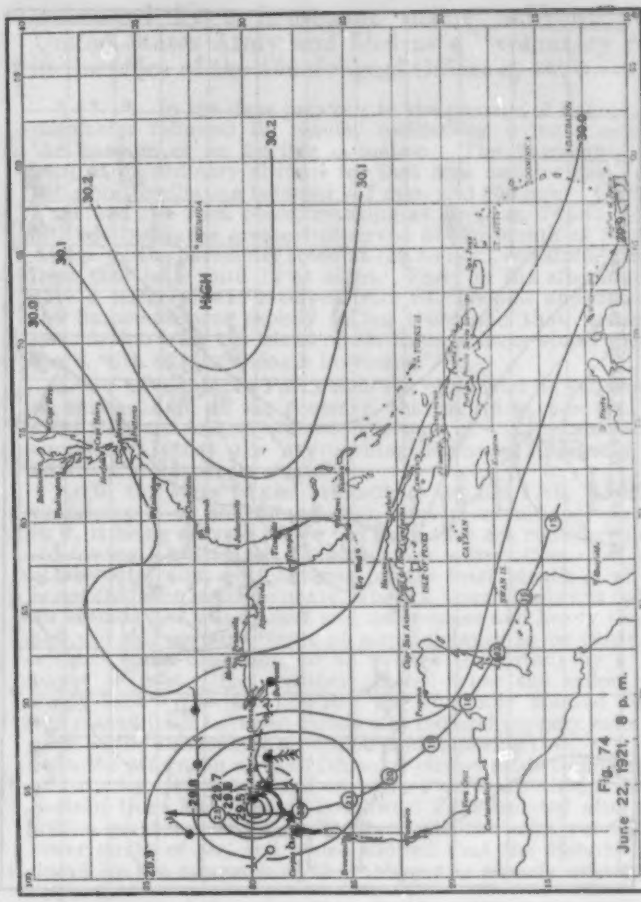


Fig. 74
June 22, 1921, 8 p.m.

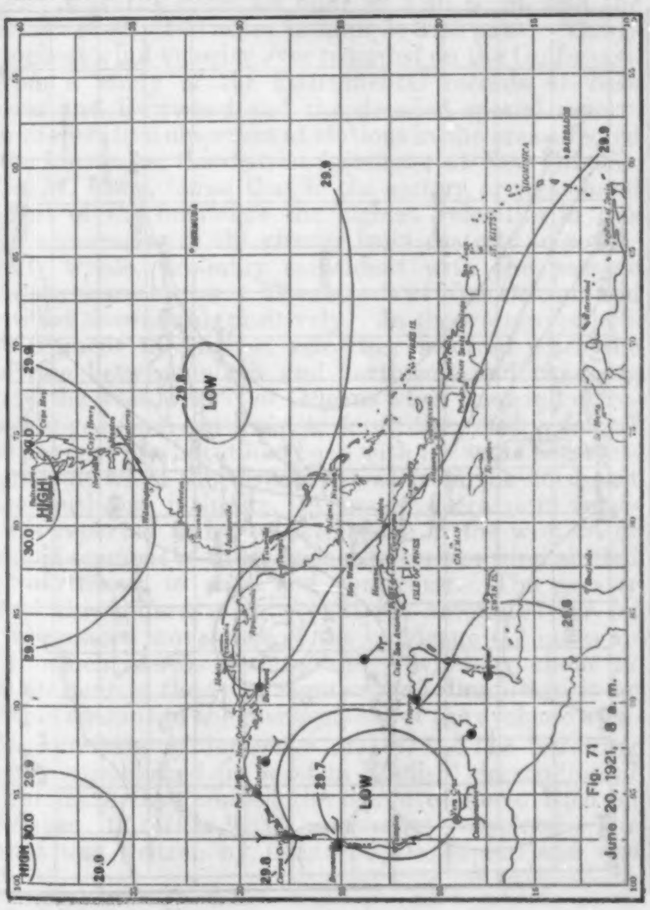


Fig. 71
June 20, 1921, 8 a.m.

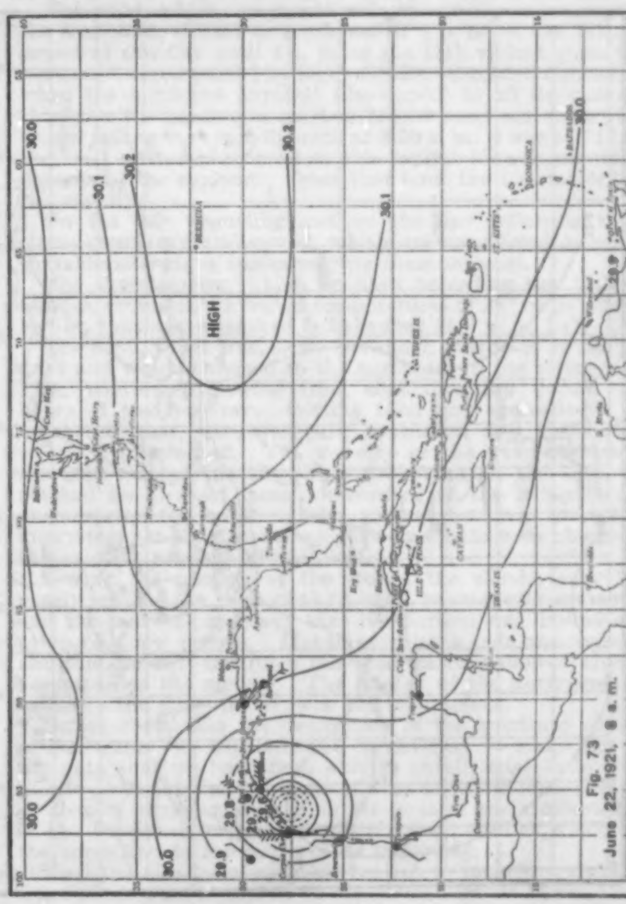


Fig. 73
June 22, 1921, 8 a.m.

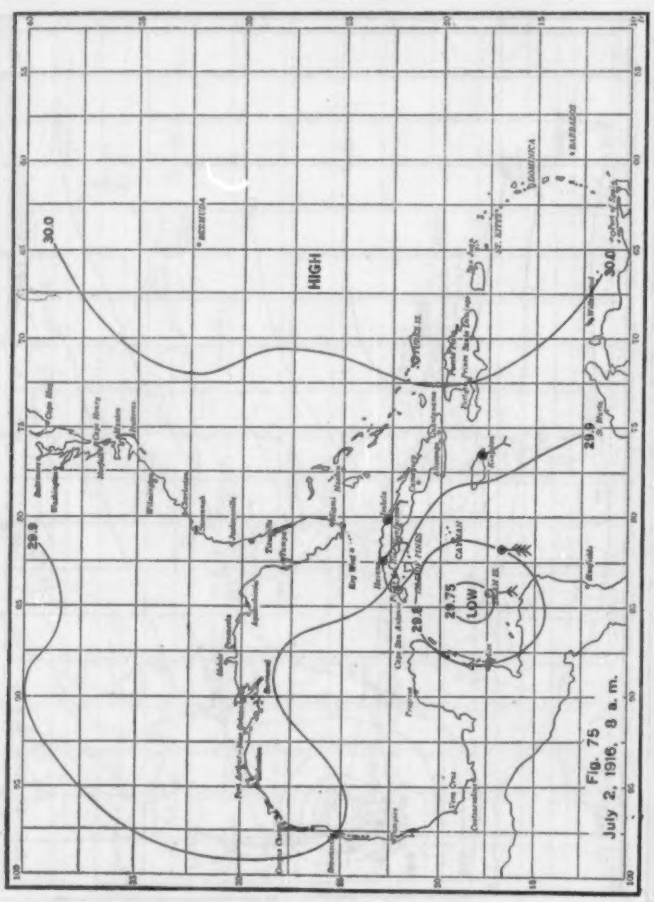


Fig. 75
July 2, 1916, 8 a.m.

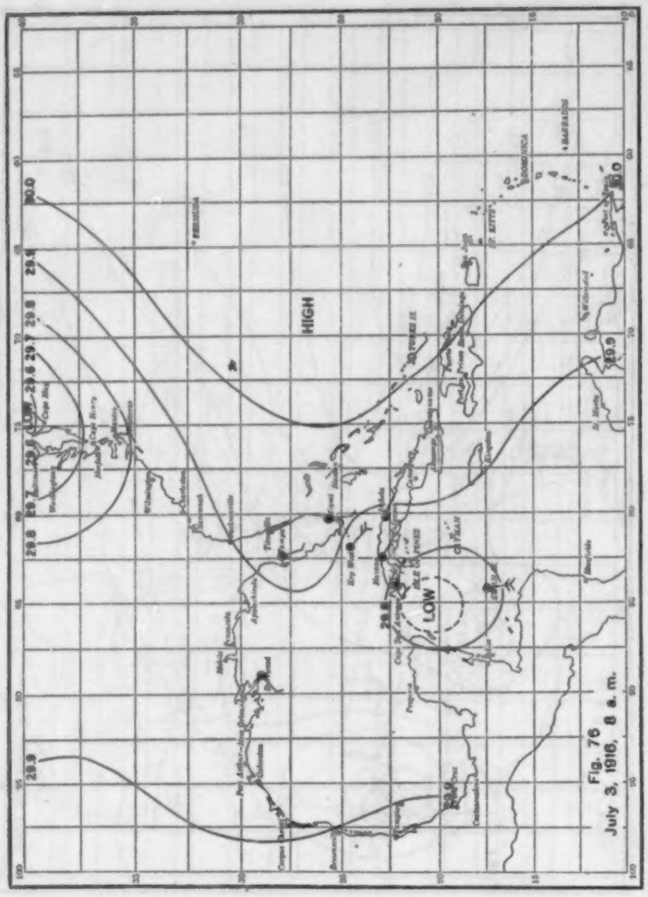


Fig. 76
July 3, 1916, 8 a.m.

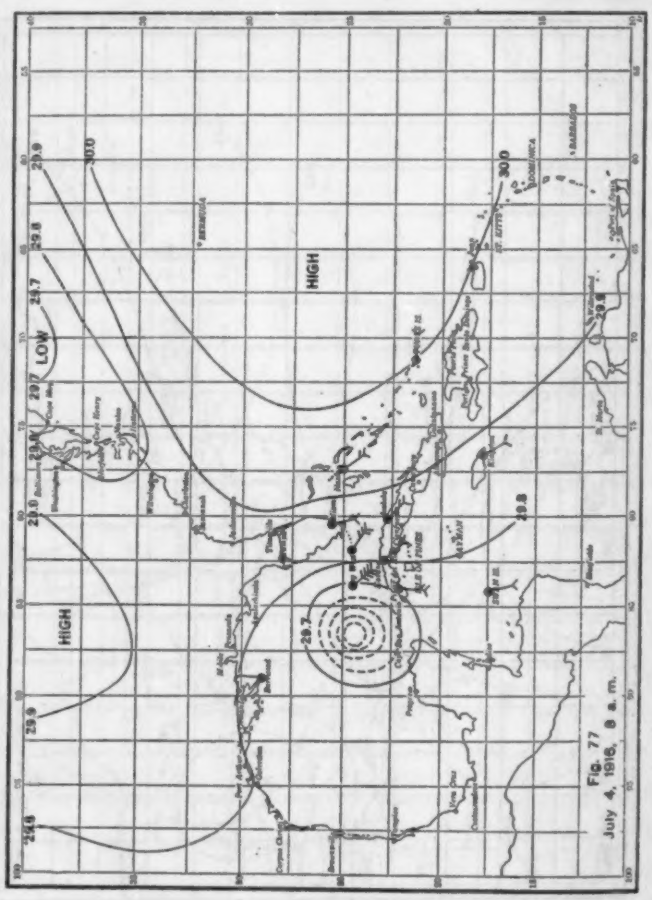


Fig. 77
July 4, 1916, 8 a.m.

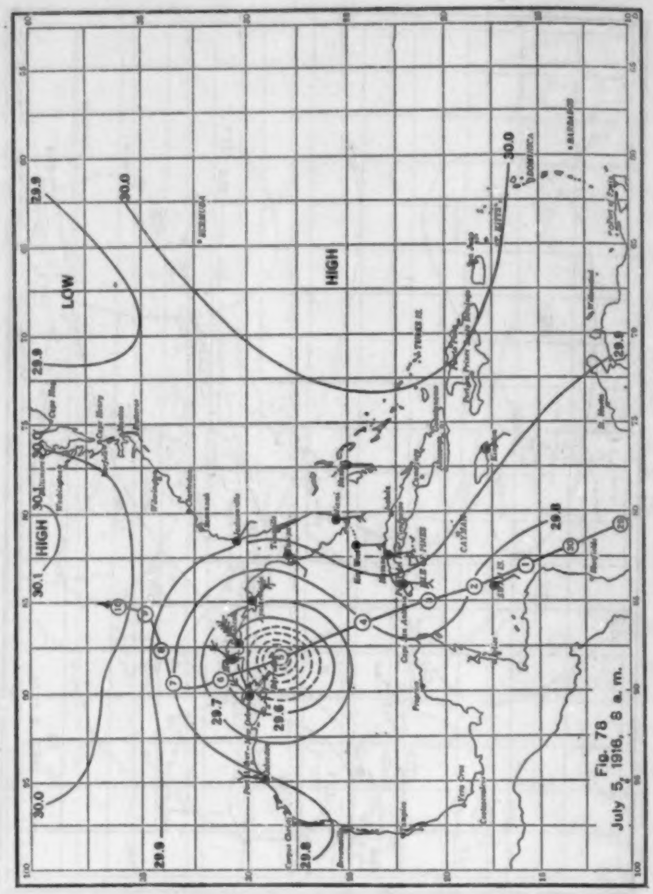


Fig. 78
July 5, 1916, 8 a.m.

The rate of movement of the storm at that time being 15 miles per hour, an area about 540 miles in diameter came within the influence of the storm as it progressed. Further details as to this very destructive storm will be found in the MONTHLY WEATHER REVIEW, August, 1915, 43:405–412.

September hurricanes.—September 22–30, 1915.—Within a little less than six weeks a second unusually severe hurricane crossed the Gulf of Mexico and advanced north-northeast to the St. Lawrence Valley.

This disturbance began as a storm of minor intensity in the vicinity of the island of Martinique, moved thence westward over the Caribbean, and then northwestward through the Yucatan Channel, greatly increasing in intensity and striking the Louisiana coast between the mouth of the Mississippi and Atchafalaya Bay. (See figs. 79–86.)

The S. S. *Hermione* at 5:30 a. m. of the 29th in latitude 27° 45′ N., longitude 90° W., barometer 27.61 inches and a gale from the north, experienced diminishing northerly winds followed by a gale from the south. Evidently the steamer was passing through the center of the storm.

At New Orleans the barometer fell rapidly from 29.54 inches at 7 a. m. of the 29th to 28.11 inches at 5:50 p. m., this being the lowest pressure ever observed at a Weather Bureau station. A trace of the barograph corrected and reduced to sea level from observed readings of the mercurial barometer is reproduced in Figure 45. The maximum wind velocity of 86 miles an hour at 5:11 p. m. was 20 miles in excess of the next highest velocity ever recorded at New Orleans. The extreme velocity was at the rate of 130 miles an hour at 4:58 p. m. At Burrwood, La., at the mouth of the Mississippi, with practically a water surface exposure, the maximum wind velocity was 124 miles an hour at 3:40 p. m. and the extreme velocity 140 miles an hour at 3:45 p. m. This is the highest wind velocity ever recorded on the Gulf coast.

From a study of the instrumental records at New Orleans and Burrwood and the detailed special reports from cooperative observers at stations in the area affected by the hurricane, the district forecaster at New Orleans, Mr. I. M. Cline, found that in the eastern or right-hand segment of the hurricane the highest velocities in this storm occurred with the change from easterly to southeasterly winds, probably coincident with the passage of the hurricane center. The records at New Orleans and Burrwood showed this positively. In the western or left-hand segment the highest velocities occurred when the wind was between north and northwest and changing toward the west. At New Orleans when the wind direction changed from southeast to south the velocity fell off to 50 per cent of what it had been with the same barometric gradient when the direction was from the northeast to the southeast, inclusive. A similar decrease in velocity was reported to have taken place in the western or left-hand segment of the hurricane when the wind shifted from northwest to west and southwest. The greater part of this difference in velocity is accounted for by the progressive movement of the hurricane (12 miles an hour), which increased the gradient wind by about 12 miles an hour in the front segment and diminished it by the same amount in the rear segment of the cyclonic area.

The hurricane of September 13, 1876.—The following hitherto unpublished (at least in English) description of the hurricane that crossed the island of Porto Rico on September 13, 1876,[17] is unusually complete. The account was written by Leonardo De Tejado and was translated by a lieutenant (name unknown) of the United States Army and filed as a "voluntary report" in the office of the Chief Signal Officer in 1877.

* * * In the days previous to the passage of the cyclone the barometer followed its regular oscillations without announcing the passage of so terrible a meteor. The barometric column kept at its ordinary altitude for that time and for that region of the globe, oscillating between 757 mm. and 760 mm. On the 12th a marked rise took place, reaching at 10 a. m. 761.45 mm., this altitude being the greatest observed in the month of September. At 4 p. m. the barometer stood at 759.55 mm., remaining stationary from that hour until 12 at night. Early in the afternoon of the 12th a telegram was received from St. Thomas announcing that the barometer was rapidly falling there and that, according to information from the island of St. Kitts, a fierce storm was raging there, with signs of being a hurricane.

As we have said, in Porto Rico the barometer as yet announced no change, and, on the contrary, that morning there had been a great rise, undoubtedly, due to the want of equilibrium (disturbed equilibrium) that the approaching hurricane produced in the adjacent atmospheric strata.

As to the state of the atmosphere on the 12th, it suffices in examining it to understand that some premonitions were shown in it, it being easy to notice the signs that are considered as foreshadowing a hurricane. The heat was sultry; there was a period of absolute calm, not changing for the least breath of air, which is not frequent in this climate, where a breeze is always felt. The air seemed less transparent and more dense and heavy than usual and did not permit objects at some distance to be distinguished without some confusion, or as twisted (distorted) by a kind of vapor or mist. The weather showed what the sailors call an "ugly look" (feo caris), which was the more marked when the sun placed itself between clouds of a red and coppery color, which gave to the atmosphere a peculiar and imposing tint.

In the afternoon of the 12th some cirro-stratus clouds appeared and during this time there crossed at quite an altitude near the horizon from northeast to southwest light isolated scud moving with a great velocity as contrasted with the calm yet felt in the lower strata of air, and which showed that the disturbance produced by the approach of the meteor was already evident in the upper air.

The wind, which, on previous days had blown constantly from the southeast, shifted to northeast at 1 p. m. of the 12th. From sunset of this day until 4 a. m. of the 13th violent gusts from the northeast, accompanied by fierce squalls, succeeded uninterruptedly when the hurricane unrolled (developed) in all its violence. At this hour the barometer marked 755.60 mm., and from then continued falling very rapidly until at 8:30 a. m. it was at 742.65 mm., the least altitude observed at this capital (San Juan) during the passage of the cyclone. From that hour the barometer began to rise rapidly.

On the day preceding and on the day following the storm cirrus clouds were observed, which are considered as one of the characteristic signs accompanying these meteors.

The thermometer, which on days preceding the 13th of September, ordinarily indicated temperatures of 28° or 30° centigrade, had on that day a marked fall showing at 9 a. m. 24°.

The wind, which was, as we have said, southeast on the previous days and which changed to the northeast in the afternoon of the 12th, continued blowing from that direction during the first hours of the hurricane, shifting then and successively to east-northeast, east, east-southeast, southeast, and south-southeast, where it terminated. The velocity of the wind increased from the afternoon of the 12th until 8:30 a. m. of the 13th, when it reached its greatest force. According to the indications of the anemometer, the mean velocity at that hour was more than 100 kilometers per hour, and some gusts or squalls were observed when the velocity reached 130 kilometers.

During the passage of the storm, the clouds, very low and nearly grazing the roofs of the houses, moved with great velocity, and the rain was so heavy that the horizon was limited at a distance of a few meters. Lightning, with a pale and yellow light, and thunder that the din of the wind scarcely allowed to be heard, accompanied the meteor. The rainfall of the hurricane, as indicated by the pluviometer, was 120 millimeters.

Before continuing the description of the hurricane of the 13th of September, we will take the opportunity to make a résumé of the data that we have been able to obtain relative to the barometric oscillations and changes of wind observed during its passage in distant localities, as well as the hour of the greatest intensity of the hurricane, naming separately the localities which were to the north and to the south of its trajectory.

We have also believed it convenient to include a statement of some observations verified in the "Jefaltura de Obras Publicas" (Bureau of Public Works).

[17] This report is published for its historical value rather than for its bearing upon the discussion in this paper.—*Editor.*

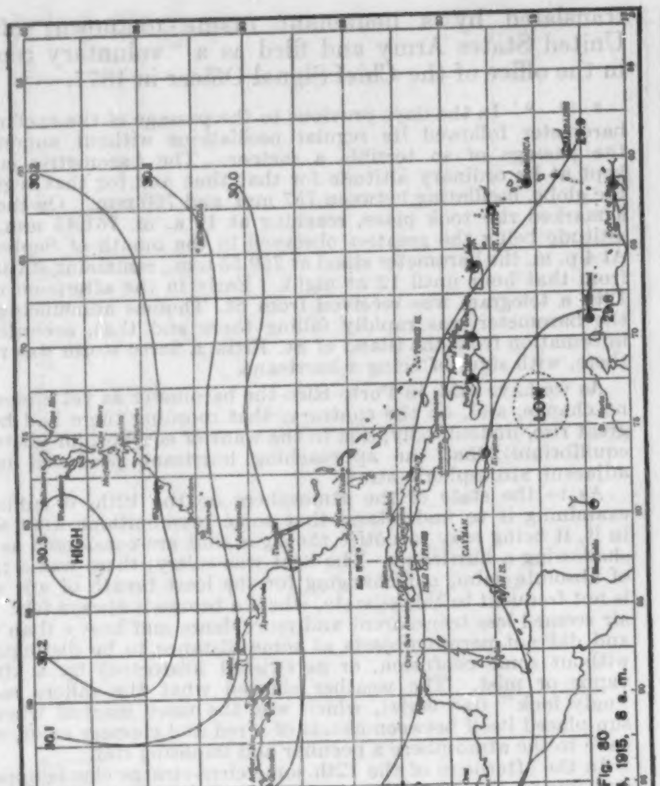


Fig. 80 Sept. 24, 1915, 8 a.m.

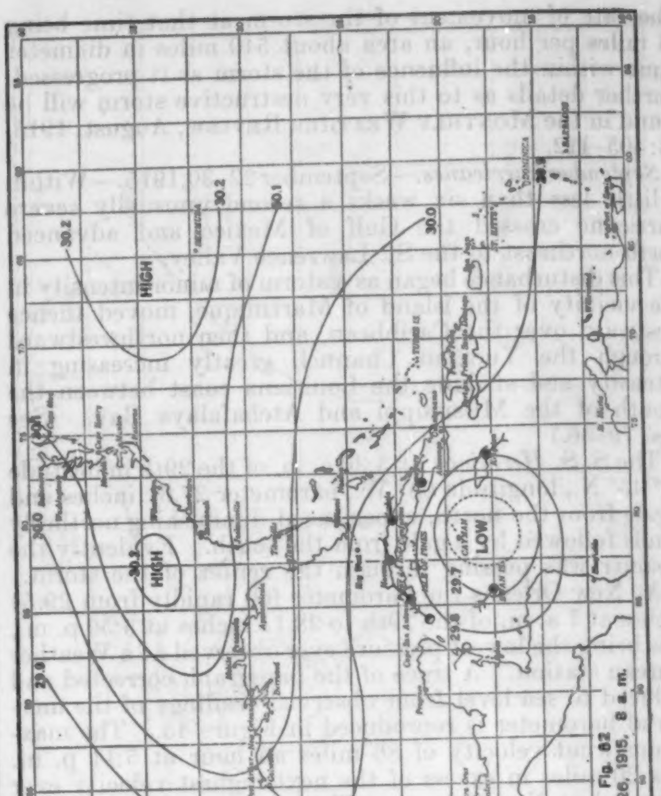


Fig. 82 Sept. 6, 1915, 8 a.m.

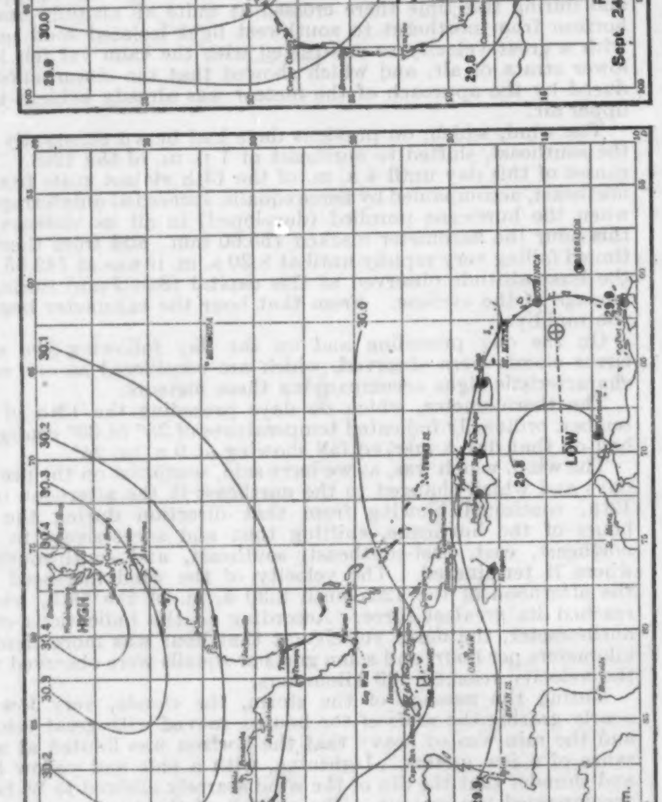


Fig. 79 Sept. 23, 1915, 8 a.m.

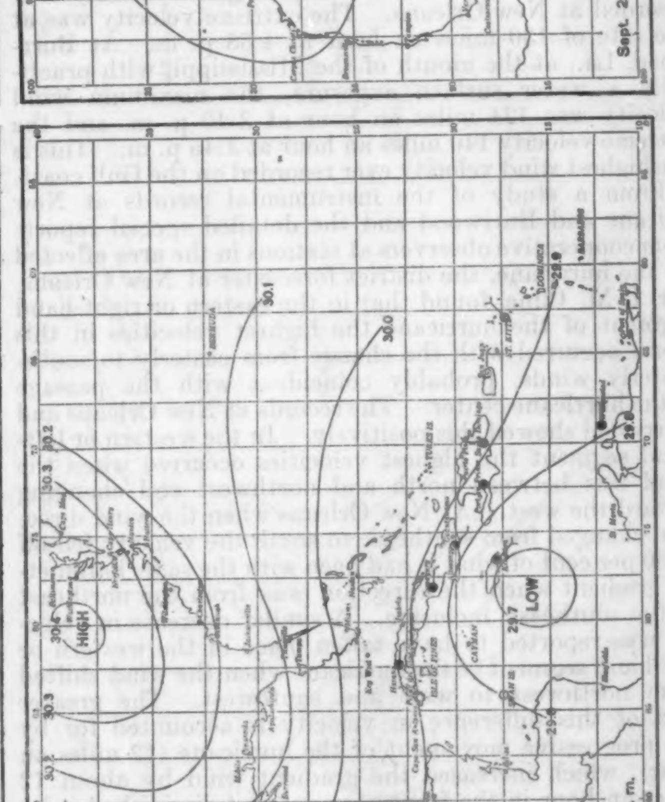


Fig. 81 Sept. 25, 1915, 8 a.m.

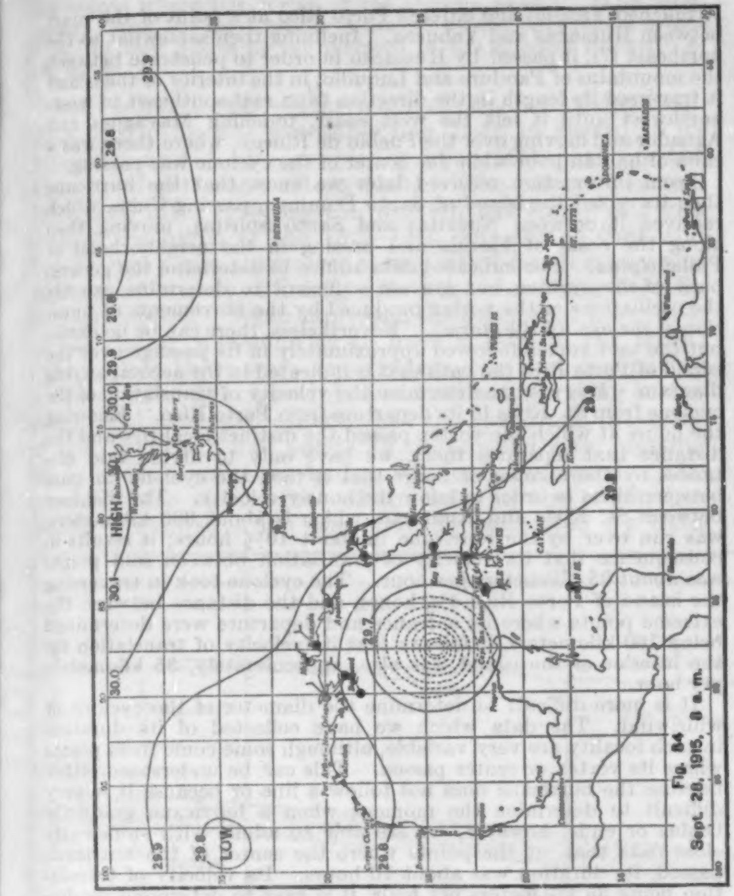


Fig. 64
Sept. 28, 1915, 8 a.m.

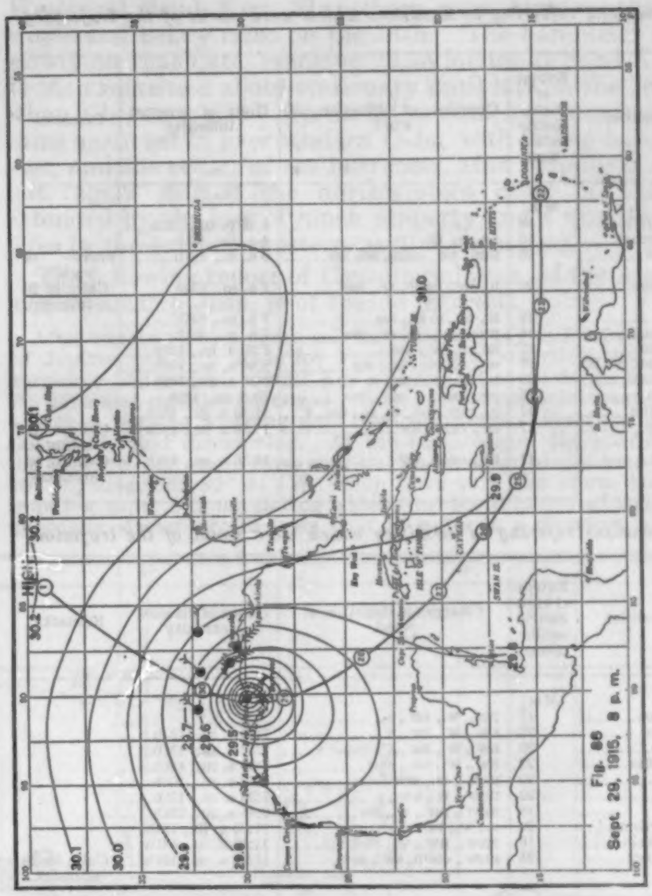


Fig. 66
Sept. 29, 1915, 8 p.m.

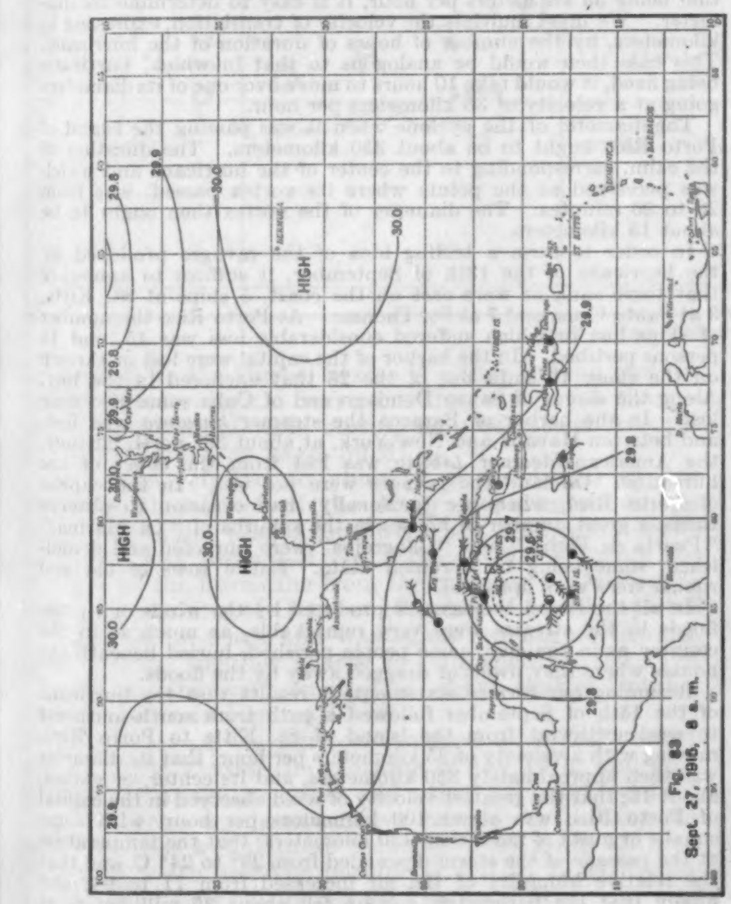


Fig. 63
Sept. 27, 1915, 8 a.m.

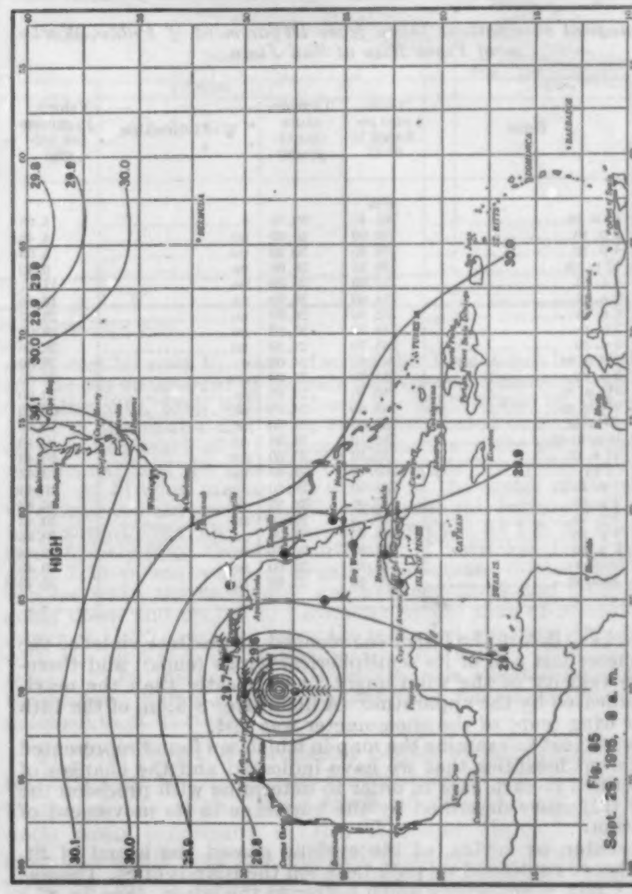


Fig. 65
Sept. 29, 1915, 8 a.m.

Observations referring to localities which were north of the trajectory

Localities	Extent of barometric oscillation	Changes of direction of wind	Hour of greatest intensity	Remarks
	Mm.			
St. Kitts	18		8:30 p. m., 12th	
St. Thomas	16	ne., e., ne. (?)	4 a. m., 13th	
Vieques	16	nne., ne., calm, se., sse	6 a. m., 13th	Focus of vortex.
Humacao	25	n., ne., calm, se., sse	7 a. m., 13th	Calm of 20 minutes.
Ceiba	18	n., ne., e, se., sse	7 a. m., 13th	
Fajardo	16	nne., ne., e., se., sse	7 a. m., 13th	
Carolina	17	ne., e., se., sse	7:30 a. m., 13th	
San Juan, P. R.	17	ne., e., ese., se., sse	8:30 a. m., 13th	
Vega Baja	20	n., ne., e., ese., se	9:30 a. m., 13th	
Arecibo	17	ne., ene., e. ese., sse	10 a. m., 13th	
Aquadilla	17	n., nne., ne., e., se., sse., s	11:30 a. m., 13th	
Aquada	17	ne., calm, sw	11:30 a. m., 13th	Calm of 20 minutes.
Rincon	17	ne., calm, sw	11:30 a. m., 13th	Calm of 30 minutes.

Observations refering to localities which were south of the trajectory

Localities	Extent of barometric oscillations	Changes of direction of wind	Hour of greatest intensity	Remarks
	Mm.			
Yabucoa	17	nw., w., sw., s		
Patillas	22	nw., w., sw., s	7:30 a. m., 13th	
Arroyo	20	nw., w., sw	7:30 a. m., 13th	
Guayama	22	nw., w., sw., ssw	7:30 a. m., 13th	
Cayey	22	nnw., w., ssw	7:30 a. m., 13th	
Coano	22	nnw., w., sw., s	7:30 a. m., 13th	
Ponce	18	nnw., nw., w., sw	9:45 a. m., 13th	
San German	20	n., w., sw	11:00 a. m., 13th	
Cabo Rajo	16	nnw., nw., w., sw., s	11:15 a. m., 13th	
Mayaguez	25	nnw., calm, sw., ssw	11:30 a. m., 13th	Calm for 20 minutes.

Meteorological observations taken from Department of Public Works of Porto Rico at San Juan

Day	Hour	Barometer reduced to 0° C.	Temperature (centigrade)	Wind direction	Velocity in meters per second
		Mm.			
Sept. 12	10 a. m	761. 45	30. 00	e	4. 63
12	1 p. m	759. 90	30. 60	ne	4. 48
12	4 p. m	759. 35	30. 80	ne	5. 03
12	12 p. m	759. 55	28. 00	ne	6. 42
13	4 a. m	755. 60	26. 60	ne	11. 11
13	5 a. m	754. 60	26. 20	ne	16.,66
13	6 a. m	752. 60	26. 00	ne	23. 33
13	7 a. m	749. 20	25. 50	ne	24. 03
13	8 a. m	743. 70	24. 50	ne	26. 66
13	8½ a. m	742. 65	24. 00	e	28. 00
13	9 a. m	744. 70	24. 00	ese	20. 00
13	9¼ a. m	746. 70	24. 00	se	20. 00
13	9½ a. m	748. 65	24. 50	se	20. 00
13	10 a. m	749. 60	24. 50	se	10. 43
13	10½ a. m	751. 10	24. 50	se	10. 43
13	11 a. m	752. 10	24. 50	sse	10. 43
13	12 m	753. 10	26. 40	sse	10. 43
13	1 p. m	755. 10	26. 60	sse	10. 43
13	2 p. m	755. 90	26. 40	sse	10. 43
13	3 p. m	756. 70	26. 20	sse	10. 43
13	4 p. m	756. 90	26. 20	se	10. 43
13	6 p. m	757. 80	26. 00	se	10. 43
13	10 p. m	758. 80	25. 60	se	10. 43
14	10 a. m	759. 60	27. 60	e	10. 43

Remarks.—Before the hurricane reached its greatest violence the anemometer lost one of its semispherical wings (cups), and therefore the velocity of the wind ought to be greater than the maximum indicated by the apparatus. A little after 8 a. m. of the 13th another wing (cup) of the anemometer was lost.

It is sufficient to examine the map in which are found represented the different localities that we have indicated and the changes of wind verified in each case in order to determine with precision the general trajectory described by the hurricane in its movement of translation.

The center, or vortex, of the cyclone passed the island of St. Kitts, thence continued its path between the islands of St. Thomas and St. Croix, approaching much nearer to the latter. (See fig. 87.) It touched Vieques and entered Porto Rico at a point of the coast between Humacao and Yabucoa. Inclining then somewhat to the northeast (?), it passed by Humacao in order to penetrate between the mountains of Pandura and Luquillo; in the interior of the island it traversed its length in the direction from east-southeast to west-northwest until it left the west coast, touching Mayaguez and Aguador and moving over the Pueblo de Rincon, where there was a calm of half an hour while the center of the cyclone was passing.

From information received later we know that the hurricane then traversed the island of Santo Domingo, passing Cuba, which received it between Nuevitas and Santo Spiritas, moving then along the coast of Florida and passing in the neighborhood of Philadelphia. The indicated data suffice to determine the general path of the cyclone, but are not sufficient to determine exactly the oscillations of the vortex produced by the movements of nutation of the eye (of the storm). Nevertheless, there can be no doubt but the said vortex followed approximately in its passage over the island of Porto Rico the path that is indicated in the accompanying diagram. It is easy to determine the velocity of translation of the cyclone from St. Kitts to its departure from Porto Rico. Knowing the hours at which the vortex passed the distinct localities and the distance that separates them, we have only to divide said distances by the number of hours that it took the cyclone to pass between them in order to know the hourly velocity. The distance between St. Kitts and Humacao, which is about 360 kilometers, was run over by the hurricane in about 10½ hours; it results in consequence that its velocity of translation between said points was about 35 kilometers per hour. The cyclone took in traversing the island of Porto Rico 4½ hours, and the distance between the extreme points where its entrance and departure were determined being 160 kilometers, it follows that its velocity of translation for the interior of the island was also, approximately, 35 kilometers per hour.

It is more difficult to determine the diameter of the cyclone or whirlwind. The data which we have collected of its duration in each locality are very variable, although some come from points where its vortex or center passed. This can be understood either because the hurricane does not follow a line or because it is very difficult to determine the moment when a hurricane gradually begins or ends; however, we are able to admit with sufficiently close data that, at the points where the center of the hurricane passed, its duration was about 10 hours. Its velocity of translation being 35 kilometers per hour, it is easy to determine its diameter. We must multiply the velocity of translation, expressed in kilometers, by the number of hours of duration of the hurricane. This case then would be analogous to that in which, hurricane being fixed, it would take 10 hours to move over one of its diameters going at a velocity of 35 kilometers per hour.

The diameter of the cyclone when it was passing the island of Porto Rico ought to be about 350 kilometers. The duration of the calm, corresponding to the center of the hurricane and which was perceived at the points where its vortex passed, was from 20 to 30 minutes. The diameter of the vortex then ought to be about 15 kilometers.

In order to form a trifling idea of the ravages produced by the hurricane of the 13th of September, it suffices to announce that there sank or were cast on the coast, 5 ships at St. Kitts, 3 at Santa Cruz, and 7 at St. Thomas. At Porto Rico the number of ships lost or which suffered considerable loss was 45, and 16 persons perished. In the harbor of the capital were lost or thrown on the shore 10 ships out of the 28 that anchored in the bay. Along the shores of Santo Domingo and of Cuba some also were lost. In the harbor of Baracoa the steamer *Saratoga* was lost, and between Havana and New York, at about 33° north latitude, the American steamer *Liberty* was lost from the effect of the hurricane. On land the ravages were not less. In the capital of Porto Rico, where we (personally) had occasion to observe them, a great number of houses in the suburbs of "La Marina," "Puerta de Fierra," and "Cangrejos" were unroofed and demolished, some being in a ruined state. Entire rows of old and robust trees were uprooted.

In all the island the ravages produced by the winds or by the floods in the streams were very remarkable, as much so in the country as in the city; some people perished, buried beneath the houses where they dwelt or dragged away by the floods.

Resuming our former statement, it results that the hurricane of the 13th of September followed a path from south-southeast to west-northwest from the island of St. Kitts to Porto Rico, moving with a velocity of 35 kilometers per hour; that its diameter was then approximately 350 kilometers, and its center, or vortex, about 15; that the greatest velocity of wind observed in the capital of Porto Rico was about 100 kilometers per hour, with some squalls or gusts of more than 130 kilometers; that the temperature at the passage of the storm descended from 28° to 24° C. and that the relative humidity of the air increased from 71 to 94; and finally that the barometric column fell about 25 millimeters at

the points where the vortex of the cyclone passed, 734.65 millimeters being the least height indicated by the barometers established at said places at the moment of the greatest intensity of the storm.

October hurricanes.—Hurricane of October 11–23, 1910: This hurricane was a notable one, both in regard to its intensity and to its decidedly abnormal path in the vicinity of extreme western Cuba. The behavior of this hurricane after crossing the western extremity of Cuba during the night of the 13th–14th was at the time and for several years thereafter a subject of much study and discussion, widely differing views thereon being held by meteorologists. Some expressed the belief that the course of the center was such as to form a loop in the track; others, that there were two centers, the first dissipating in the Gulf of Mexico while a second was forming to the southward; and still others, that the speed and intensity of the hurricane had suddenly diminished after passing into the Gulf and then had as suddenly increased. The first of these views, that of the loop in the track, has finally prevailed upon the showing presented by data assembled by the United States Weather Bureau and the Cuban Meteorological Service. The reasons for the peculiar behavior of this storm, as understood by the writer, are given on pages 30–31.

The data referred to above were published by the Hydrographic Office of the Navy Department on the back of the Pilot Charts for November, 1922, and a series of charts was presented (see Figs. 46–53) showing the features of the hurricane from the morning of October 12 until the morning of October 17, when it had completed the loop in its track and was again moving northward. The 8 a. m. weather charts as published on the Pilot Charts, together with one 8 p. m. chart, that of October 16, are shown in Figures 46–53.

The center of the hurricane passed over the western end of Cuba during the morning of the 14th, and considerable damage to crops and other property resulted from the high winds and heavy rains. At Habana the wind reached a maximum velocity of 88 miles an hour from the south and the barometer fell to 29.04 inches, but it fell below 29 inches at Pinar del Rio. At Key West and Sand Key, Fla., there were high southeast winds and heavy rains on the 14th. The barometer fell slowly on that date, reaching 29.55 inches at Sand Key. It then remained about stationary until late on the 16th, when it began to rise. On the latter date, however, heavy rains again set in over western Cuba, with falling barometer, and the center of the hurricane, after looping to the left, again skirted the northwestern coast of Cuba, attended by the loss of much property and a number of lives in the extreme western part of the island.

The following report of Captain Sullivan, of the American steamship *Jean*, is of special interest:

After running into a fierce gale in which she lay to for 24 hours off Jupiter, the ship made for Florida Strait, expecting that the hurricane had passed. Sand Key was passed at 11:55 p. m. on the 16th and signals exchanged. Ship headed east-southeast. It was then blowing a strong gale from an easterly direction, with sky cloudy and threatening. At the beginning of the hurricane the position was made from well-known landmarks—latitude 24° 26′ N., longitude 82° 41′ W. Ship hove to. The storm lasted from 5 a. m. to 8 p. m., during which time the ship drifted against unusually strong stream from Gulf 60 miles in a direction west-southwest by west ½ west. During this time it was impossible to see the sea on account of the rain and spray. Immense seas came over the ship, even wetting down the chart house on the bridge deck, so that water had to be constantly baled out. Boats were stove in and much of the fittings loosened, and the port bow plate was dented as if the ship had run into some heavy fixed obstruction. At 11:25 a. m. the ship arrived at the center of the storm. Overhead the sky was perfectly clear, but the horizon was dirty, wind almost calm, and sea fearfully choppy. At 1 p. m. the wind came fiercely from the west-northwest of hurricane force, lasting until 7:30 p. m., when it began to moderate. The wind blew hardest when the barometer was between 28.10 and 28.30, both going down and up. The barometer at the time of reaching the center at 11:25 a. m. was below the scale, but was carefully marked with the set hand, and subsequently with a file. This was, corrected, 27.80 inches. The barometer rose slightly on entering the center. Ship's position at that time was approximately 27 miles south of Tortugas.

At Sand Key the barometer began to fall rapidly about midnight of the 16th and reached 28.62 inches at 12:20 p. m. of the 17th. The force of the wind drew large nails from the doors of the Weather Bureau building, and the sand was all washed from sight by this time, monster waves breaking over the whole island, reaching

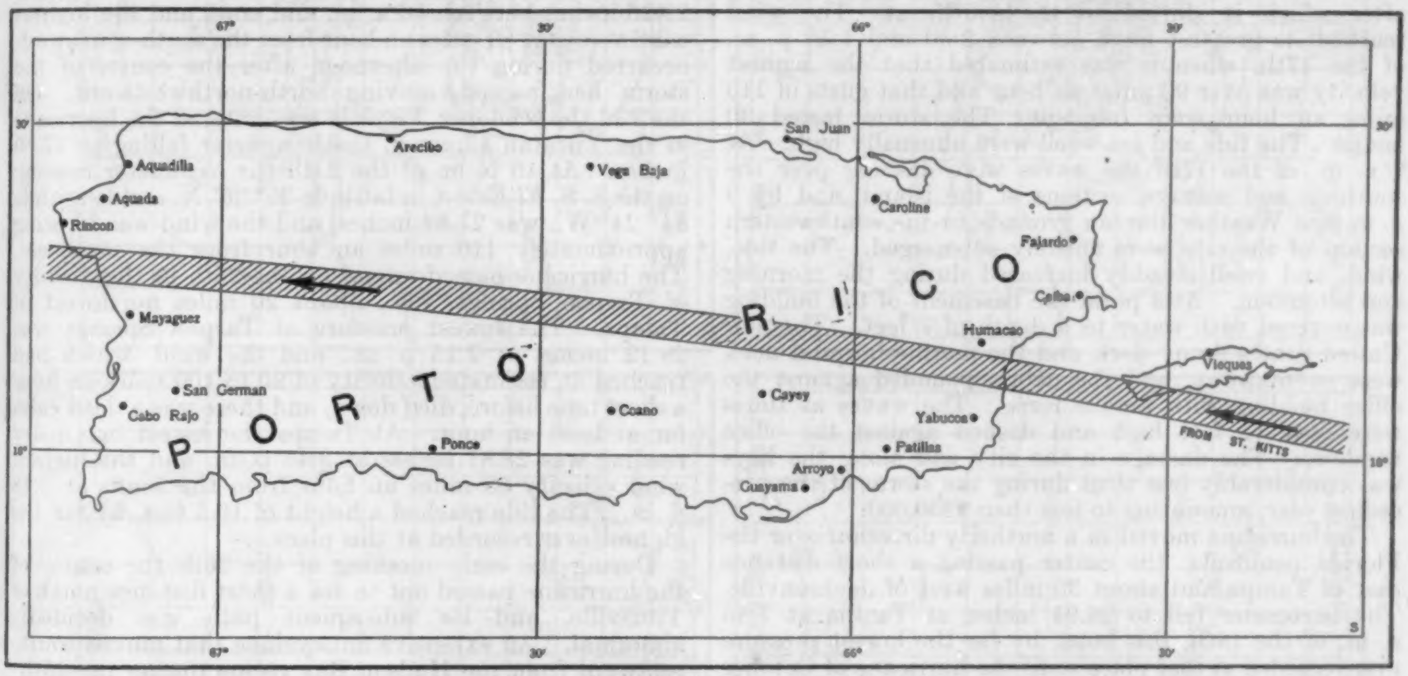


FIG. 57.—Track of hurricanes across Porto Rico

nearly up to the water tanks. The wind blew from the southeast up to 1:05 p. m., when it changed to south. The velocity increased and the swaying of the building stopped the clock several times. The estimated maximum velocity was 125 miles an hour. At 1:30 p. m. the boathouse went to pieces and was washed into the sea. At 1:50 p. m. the barometer reached its lowest point—28.40 inches. The barometer began to rise slowly, but the wind continued with unabated fury until about 6 p. m., when it diminished and shifted to southwest.

Conditions at Key West were quite like those obtaining at Sand Key, the barometer reaching its lowest point—28.47 inches—at 3:20 p. m. of the 17th. High northeast winds, varying in velocity from 30 to 50 miles an hour, with gusts of 60 miles an hour, prevailed from midnight to 8 a. m. of the 17th, shifting to southeast shortly thereafter and increasing in velocity. At 12:25 p. m. the wires to the anemometer cups were torn away by the wind when it reached a velocity of 72 miles an hour. From 3 to 4 p. m. the wind was from the south, after which it shifted to the southwest. The wind reached its greatest force between 2:30 and 4:30 p. m. of the 17th, when it was estimated that the highest velocity was over 90 miles an hour and that gusts of 110 miles an hour were frequent. The storm lasted 30 hours. The tide and sea swell were unusually high. At 7 a. m. of the 17th the waves were dashing over the southern and western sections of the island, and by 9 a. m. the Weather Bureau grounds in the southwestern section of the city were entirely submerged. The tide, wind, and swell steadily increased during the morning and afternoon. At 3 p. m. the basement of the building was covered with water to a depth of 7 feet. The new United States Army dock and the marine hospital dock were swept away, and the débris pounded against the office building with terrific force. The waves at times were over 15 feet high and dashed against the office windows. The damage in the city and along the keys was considerably less than during the storm of the preceding year, amounting to less than $250,000.

The hurricane moved in a northerly direction over the Florida peninsula, the center passing a short distance east of Tampa and about 30 miles west of Jacksonville. The barometer fell to 28.94 inches at Tampa at 7:45 a. m. of the 18th, this being by far the lowest pressure ever recorded at that place until the hurricane of October 1921, when it reached 28.81 inches. The maximum wind velocity at Tampa was 48 miles an hour from the northeast, while at Jacksonville it was 56 miles an hour from the same direction. The lowest barometer reading at the latter place was 29.09 inches at 12:30 a. m. of the 19th. At Savannah, Ga., the highest wind velocity was 70 miles an hour from the northeast and at Charleston, S. C., 58 miles an hour from the east. The lowest pressure observed at Savannah was 29.30 inches at 2 p. m. of the 19th and at Charleston, 29.39 inches at 6:30 p. m. Considering the severity of the storm, there was a remarkably small loss of life and of vessels at sea; moreover, the property damage, especially in Florida, was not as great as might have been expected.

Further details of this storm will be found in MONTHLY WEATHER REVIEW, **38**: 1488–1491, and the back of the Pilot Chart for November, 1922.

Other October hurricanes.—Hurricane of October 21–30, 1921: This hurricane is unique in two respects—first, in that it is the only tropical storm of hurricane intensity that developed after the middle of October and entered the Gulf of Mexico during the period 1887–1923, inclusive; and, second, in that it moved in a direction south of east after leaving the Florida coast. (See figs. 88–95.)

The first signs of the development of this storm were observed about halfway between Swan Island and the Isthmus of Panama on the morning of the 21st. However, the chief hydrographer, Panama Canal, reported that the barometer at Balboa Heights steadily declined, disregarding diurnal fluctuations, from October 13 to 18, preceding the birth of the hurricane. This period was accompanied by heavy daily rains, noticeably on the Pacific half of the Canal Zone, with *northerly* winds prevailing. On the 18th there was a reversion to a more or less steady *southerly* wind of dry season intensity and with dry season characteristics, except as to direction; this condition continued until the 29th. During the 20th–22d, inclusive, the wind movement at Balboa Heights averaged 19.4 miles per hour, as compared with a normal October movement of 6.4 miles per hour.

By the time the storm reached the vicinity of Swan Island on the 22d it had attained hurricane intensity. The station on that island reported a barometer reading of 29.20 inches between 10 a. m. and noon and the highest wind velocity, 80 miles an hour from the south-southwest, occurred during the afternoon after the center of the storm had passed, moving north-northwestward. On the 23d the schooner *Virginia* encountered the hurricane in the Yucatan Channel, the barometer falling to 27.80 inches. At 10 p. m. of the 24th the barometer reading on the S. S. *El Estero*, in latitude 25° 36′ N. and longitude 84° 24′ W., was 27.84 inches, and the wind was blowing approximately 110 miles an hour from the southeast. The hurricane passed inland on the 25th in the vicinity of Tarpon Springs, Fla., about 20 miles northwest of Tampa. The lowest pressure at Tarpon Springs was 28.12 inches at 2:15 p. m., and the wind, which had reached an estimated velocity of 80 to 100 miles an hour a short time before, died down, and there was a dead calm for at least an hour. At Tampa the lowest barometer reading was 28.81 inches at 2:45 p. m. and the highest wind velocity 68 miles an hour from the south at 2:18 p. m. The tide reached a height of 10.5 feet, by far the highest ever recorded at this place.

During the early morning of the 26th the center of the hurricane passed out to sea a short distance north of Titusville, and its subsequent path was decidedly abnormal. An extensive anticyclone that moved southeastward from the Hudson Bay region during the 25th–28th controlled the air movement aloft over the Atlantic States and the ocean some distance to the eastward to such an extent that the course of the storm was changed from northeast to east and later to east-southeast for at least two days. By this time (the 28th) the hurricane was centered almost due south of Bermuda. On the 27th the S. S. *Aryan* encountered the hurricane in 28° 20′ N. latitude and 70° 30′ W. longitude, and at 1 p. m. the barometer read 28.96, with an easterly wind, force 12. By the 29th the storm was central southeast of Bermuda, and it was now out of the influence of the anticyclone above mentioned. It moved rapidly northeastward during the next few days and partially merged with an extensive area of low pressure that remained almost stationary for several days over the region between latitudes 30° and 55° N., and longitudes 40° to 50° W.

November hurricanes.—Hurricane of November 11–19, 1912: There were only two tropical storms of known hurricane intensity in the North Atlantic Ocean during the period, 1887–1923, inclusive. The first was that of November 17–29, 1888, which caused very severe damage to shipping from Cape Hatteras to Eastport, Me. The

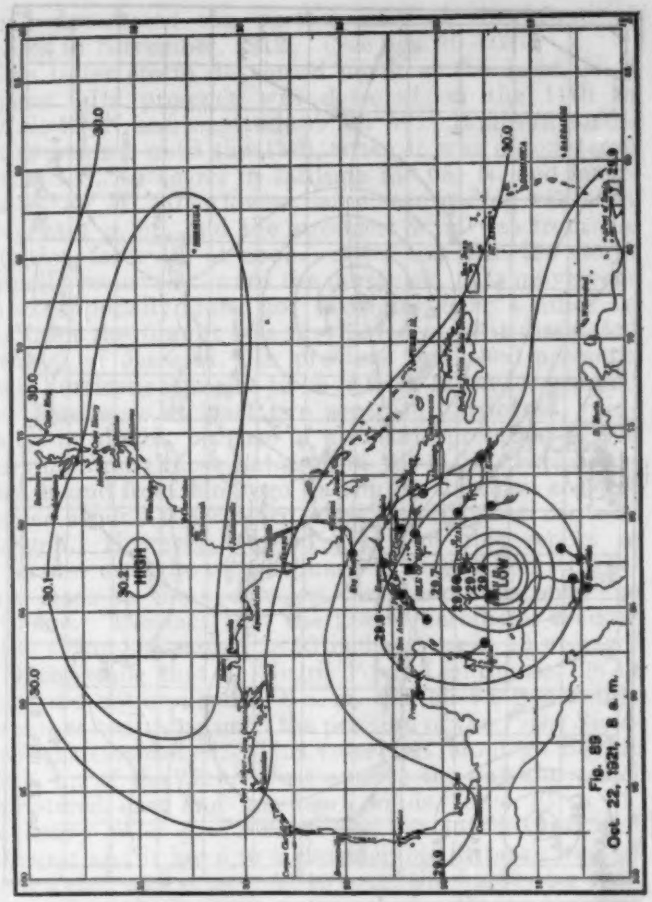


Fig. 89
Oct. 22, 1921, 8 a.m.

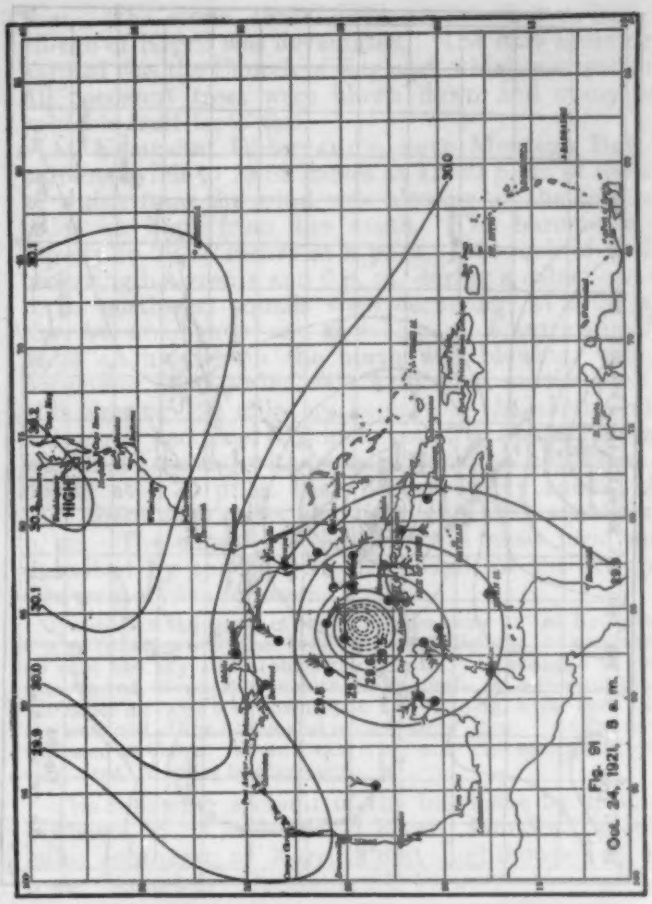


Fig. 91
Oct. 24, 1921, 8 a.m.

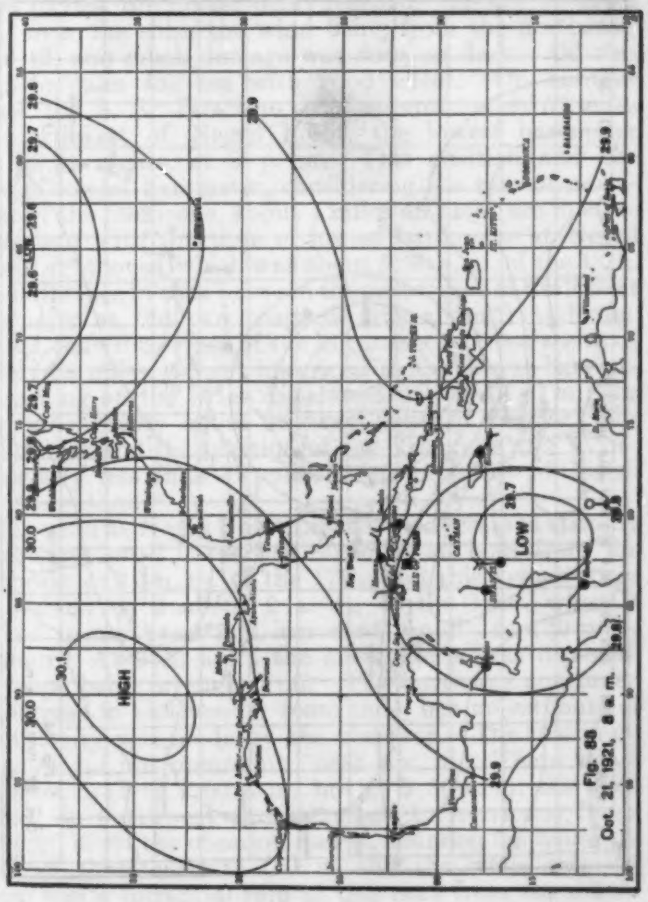


Fig. 88
Oct. 21, 1921, 8 a.m.

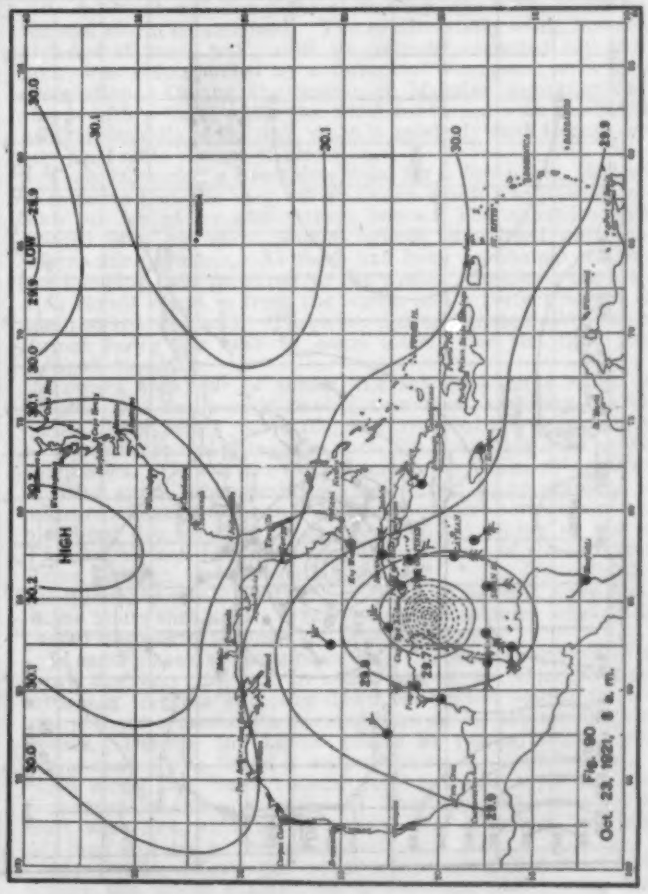


Fig. 90
Oct. 23, 1921, 8 a.m.

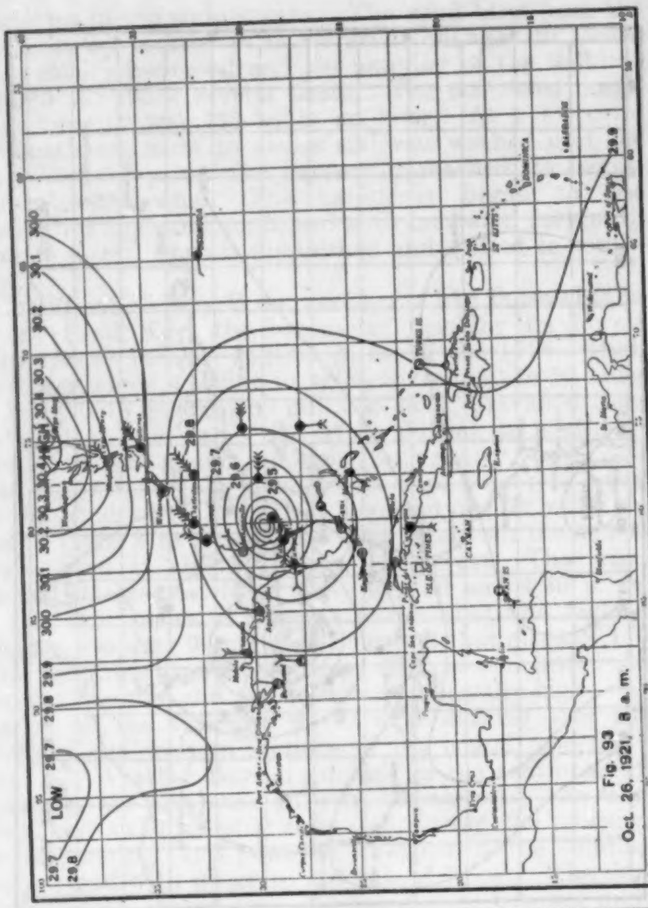


Fig. 93
Oct. 26, 1921, 8 a.m.

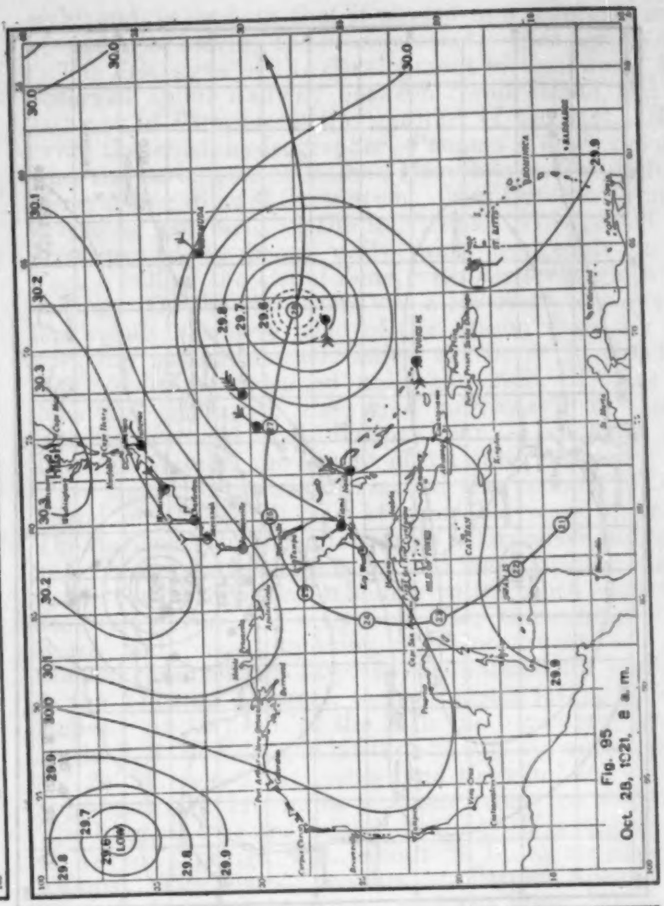


Fig. 95
Oct. 28, 1921, 8 a.m.

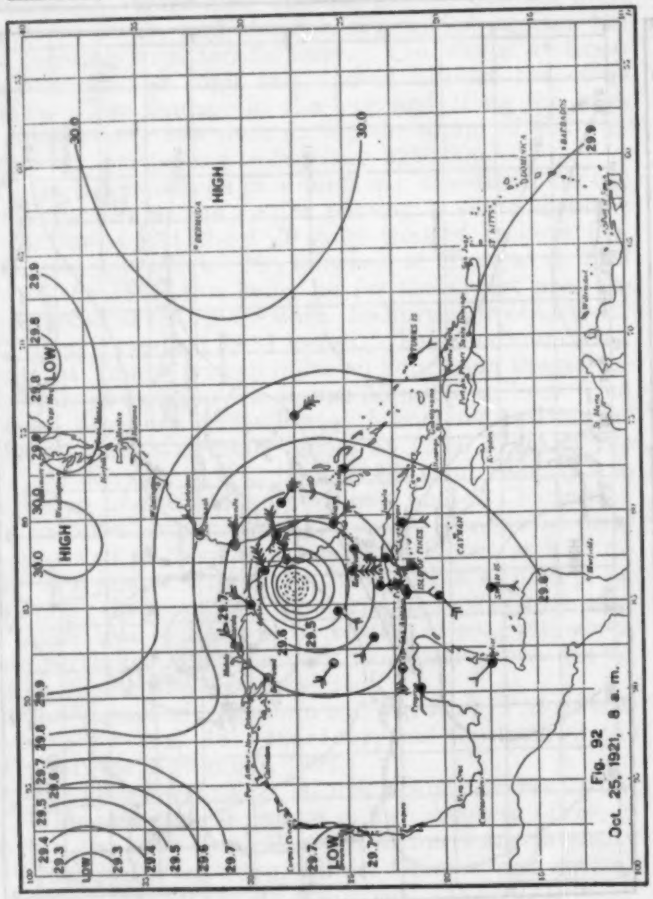


Fig. 92
Oct. 25, 1921, 8 a.m.

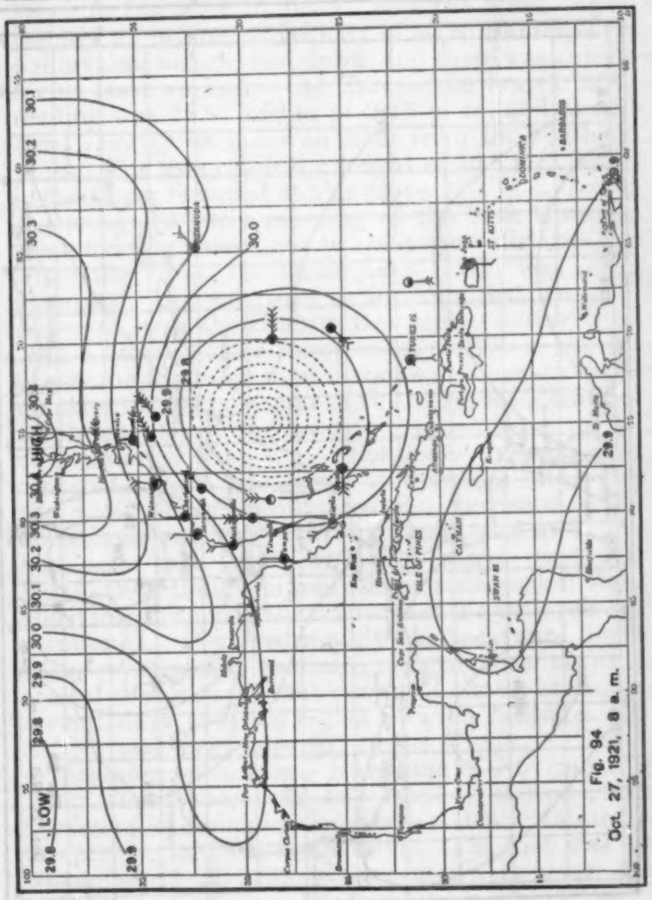


Fig. 94
Oct. 27, 1921, 8 a.m.

second devastated the western part of the island of Jamaica in November, 1912. (See figs. 96–103.)

This latter storm developed north of the Isthmus of Panama. Its presence was detected on the 11th in latitude 11° N. and longitude 80° 30′ W. It moved north-northwestward until the 13th, when it was encountered by the S. S. *Abangarez* in latitude 14° 05′ N. and longitude 81° 30′ W. The lowest barometer reading was 29.24 inches at 4 p. m., and the strongest wind was from the northeast, force 10, at noon. After the 13th the storm gradually recurved toward the northeast. Its movement was exceptionally slow, not averaging over 4 miles an hour from the time it was first noted until it dissipated northeast of Jamaica. In previous published accounts of this hurricane it seems to have been taken for granted that there were at least two separate hurricanes, principally, no doubt, because of a misinterpretation of the report of First Officer Peterson of the S. S. *Prinz Sigismund*, bound from Montego Bay on the northern coast of Jamaica around the western end of the island en route to Kingston. However, careful study of this report in connection with the records made at Negril Point Lighthouse leads to the conclusion that there was only one hurricane. The fact that the lowest barometer reading on the *Prinz Sigismund*, 28.93 inches, was at 10 p. m. of the 17th, while that at Negril Point Lighthouse, 28.49 inches, did not occur until 6 a. m. the following morning, was rather confusing until the position of the *Prinz Sigismund* was established. This vessel left Montego Bay at 5:30 p. m. of the 17th. Just outside the bay the vessel encountered east and northeast winds, force 10 to 11. The heavy wind drove the vessel far to the west and southwest and it hove to a considerable distance west of Negril Point at 9 p. m. At 10 p. m. the barometer read 28.93 inches, the lowest point reached. Heavy breakers went over the ship, the wind being from the northeast, force 12, and much damage was done on deck. Oil was used to calm the sea with good effect. On another vessel, the S. S. *Tintoretto*, was approximately 60 miles westnorthwest of Negril Point, the lowest barometer was 29.24 inches, at 3 p. m. This position and the time of lowest barometer, considering the rate of movement of the hurricane, about 4 miles an hour, are in close agreement with the time of lowest barometer at Negril Point Lighthouse, which was about 5:30 a. m. of the 18th. The difference in time between the occurrence of the lowest barometer at the two positions was about 14½ hours. In that time the center of the hurricane traveled approximately 58 miles. Now, inasmuch as the lowest barometer reading on the *Prinz Sigismund* was at 10 p. m., she was undoubtedly about halfway between Negril Point Lighthouse and the position of the *Tintoretto* at 3 p. m., or slightly less than 30 miles west-northwest of Negril Point Lighthouse.

The wind at Negril Point Lighthouse increased steadily in strength until it reached 80 miles an hour from the southeast at 10 p. m. of the 17th, and this velocity was maintained until about 2 a. m. of the 18th, when it backed to northeast and increased rapidly to 120 miles an hour. At 2:03 a. m. the anemometer was disabled, two cups being wrenched off. The hurricane continued to increase in violence for some time, but no estimate of the velocity was made by the observer. The minimum pressure did not occur until near 6 a. m. There was a lull from 5:15 to 8:00 a. m., but at 9:30 a. m. the wind backed to northwest and increased to hurricane force. At 10:20 a. m. the observer had to abandon his house, as the roof threatened to fall in and the walls cracked. There was a torrential rain at this time from the northwest. The storm ceased between 3 and 4 p. m.. The village of Negril was devastated. The only building unharmed was the Church of England, which was quite new. All cocoanut trees were blown down and many other valuable fruit trees also.

At Kempshot Observatory, near Montego Bay, the barometer fell to 29.02 inches at 12:30 p. m. of the 18th, at which time the wind was blowing at the rate of 80 miles an hour from the south. The barometer rose rapidly to 29.44 inches at 6 p. m., 0.15 inch of this rise occurring between 4 and 6 p. m. during a calm. At 6:15 p. m. northwest squalls were occurring; at 6:25 p. m. they became heavy; and at 6:35 p. m. a hurricane of 120 miles an hour from the north was blowing, with the barometer at 29.30 inches. At 6:45 p. m. the wind was still blowing 120 miles an hour from the north and the barometer had risen 0.03 inch. At 7 p. m. the barometer was 29.28 inches, with squalls from the northwest and north; at 7:30 p. m. they became heavy again. After that there were gusts and lulls with light squalls at 11 p. m. The sunset on the 18th was most lurid and is described by the late Maxwell Hall, of the Kempshot Observatory, as follows:

> Just before the worst of the hurricane came on (at Kempshot at 6 p. m.) there was a most brilliant, yellow light in the confused sky all over the sky and around the horizon. It changed to orange, then to red, clouded over with dark squalls, and the hurricane of 120 miles an hour was down upon us. The light was seen all over the west end of the island and caused some alarm. At Falmouth it was seen at night. When I saw it we were just emerging from the calm area, 20 miles in diameter.

The following account of the hurricane by Rev. J. J. Williams, S. J., of Black River, Jamaica (about 40 miles southeast of Negril Point Lighthouse), is taken from "America," December 21, 1912:

> * * * It was the night of Sunday, the 17th, however, that the real storm commenced. The southeasterly wind, increasing in violence at every puff, until its velocity exceeded 150 miles per hour, was accompanied by a torrential downpour, such as passes description. During the course of Monday morning the rains stopped for a time, while the wind continued with unabated fury until the middle of the day, when it suddenly sank to rest, without any noticeable change of direction.
>
> Then succeeded a breathless calm for a few hours, that seemed to indicate that the very vortex of the storm was passing over us. This lull lasted for about three hours. The unnatural stillness, marred only by an occasional drizzle, was itself portentous of approaching trouble. As there had been no change of the wind, the knowing ones prepared for the worst. Suddenly the low-scudding clouds swept in from the north, and a perfect deluge of rain again swept the land. The wind did not immediately resume its former fury; that was to come later. For the time being it moaned dismally.
>
> Toward the hour of sunset the sky took on a most terrible aspect. No one recalls having ever seen anything of its kind before. The heavy yellow fog that mystified the world subsequent to the eruption of Krakatoa some 30 years ago was nothing in comparison. It was like the judgment day. The rain was coming in fitful gusts, when suddenly we seemed to be standing in the midst of a blazing furnace. Around the entire horizon was a ring of blood-red fire, shading away to a brilliant amber at the zenith. The sky, in fact, formed one great fiery dome of reddish light that shone through the descending rain. * * * Then burst forth the hurricane afresh, and for two hours or more (I have lost track of the hours that night) it raged and tore asunder what little had passed unscathed through the previous blow.
>
> In some places, as Savanna la Mar, the ocean swept in and carried away the very débris. In other places, as Montego Bay, the inrushing torrents sweeping down the gullies leaped their banks and without a moment's warning bore out to sea row after row of houses. Despite the heroic efforts at rescue, many were the unfortunates who found a watery grave.
>
> All along the coast vessels were wrecked upon the reefs or foundered in the open sea. At Montego Bay alone 14 sailing craft were lost, while at Savanna la Mar more than one hulk was left high and dry in the public market.
>
> Meanwhile, inland the wind was playing havoc everywhere, wiping out whole plantations of bananas, obliterating fields of

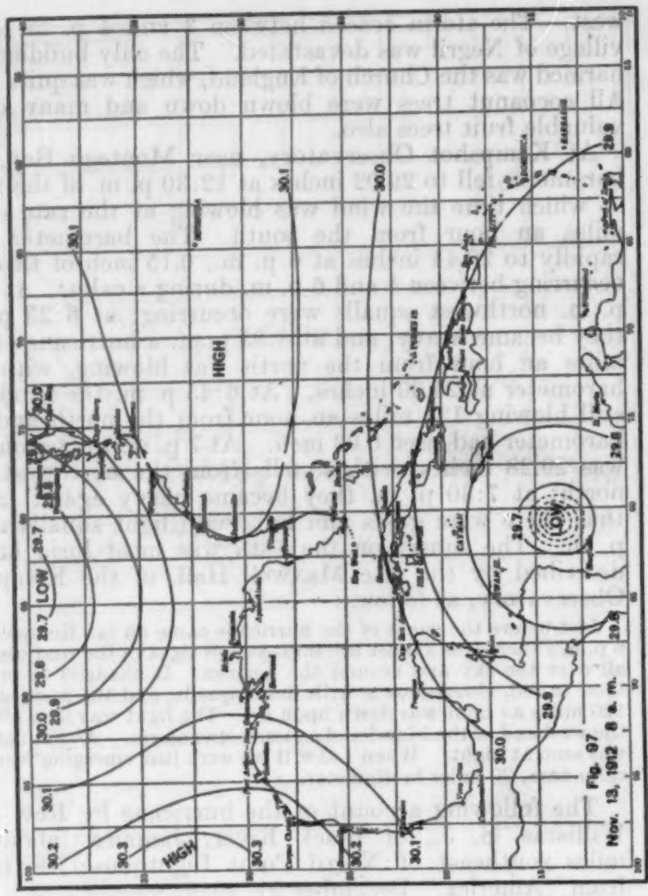


Fig. 97
Nov. 13, 1912 8 a.m.

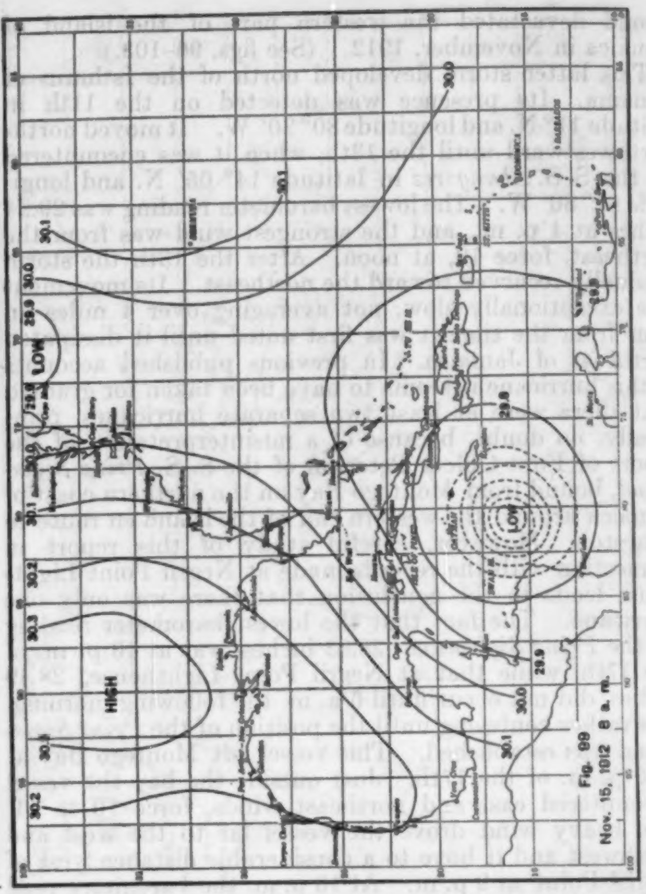


Fig. 99
Nov. 15, 1912 8 a.m.

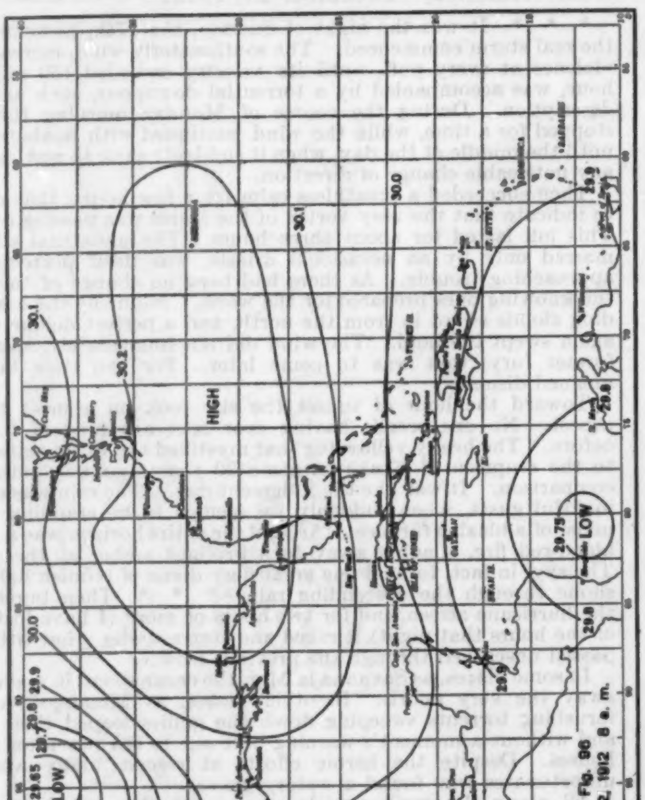


Fig. 96
Nov. 12, 1912 8 a.m.

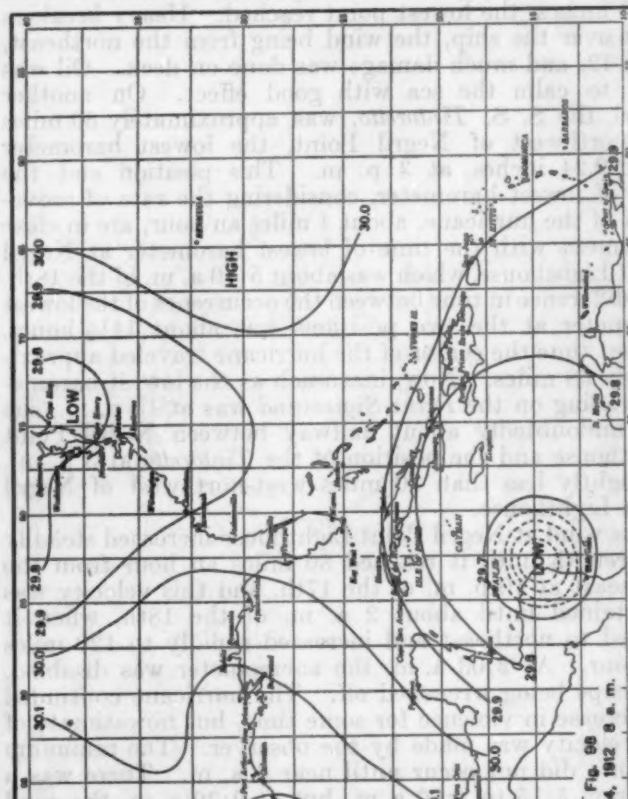


Fig. 98
Nov. 14, 1912 8 a.m.

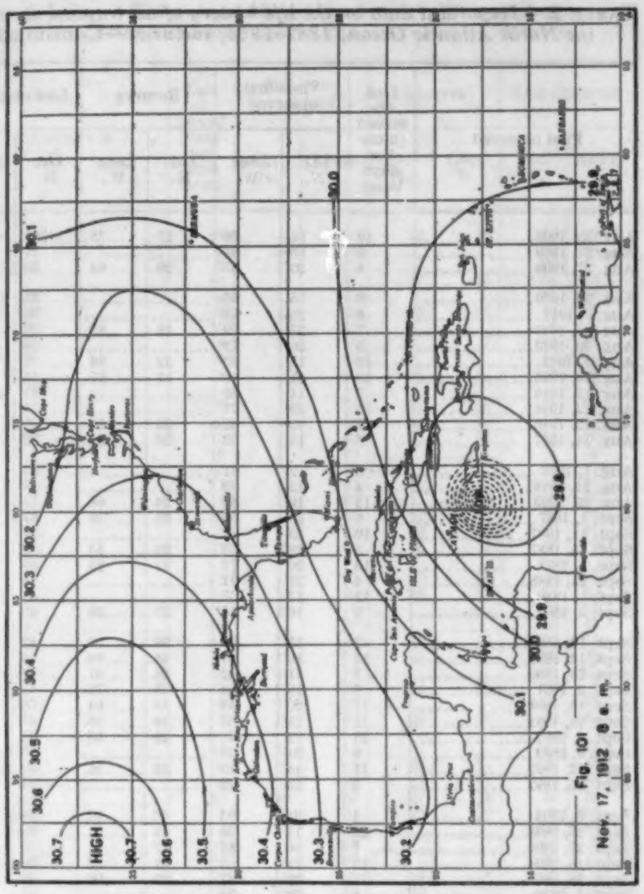


Fig. 101 Nov. 17, 1912 8 a. m.

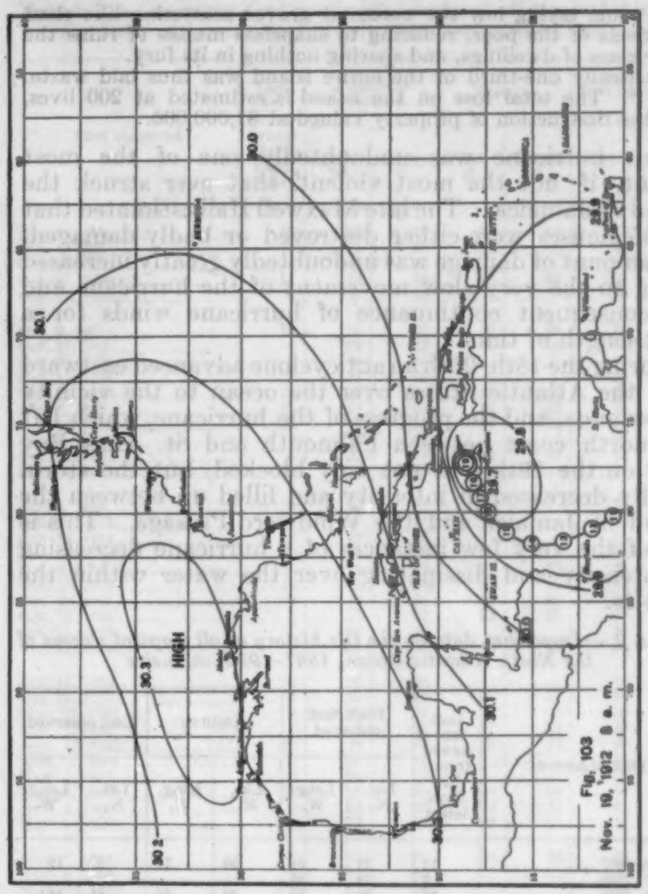


Fig. 103 Nov. 19, 1912 8 a. m.

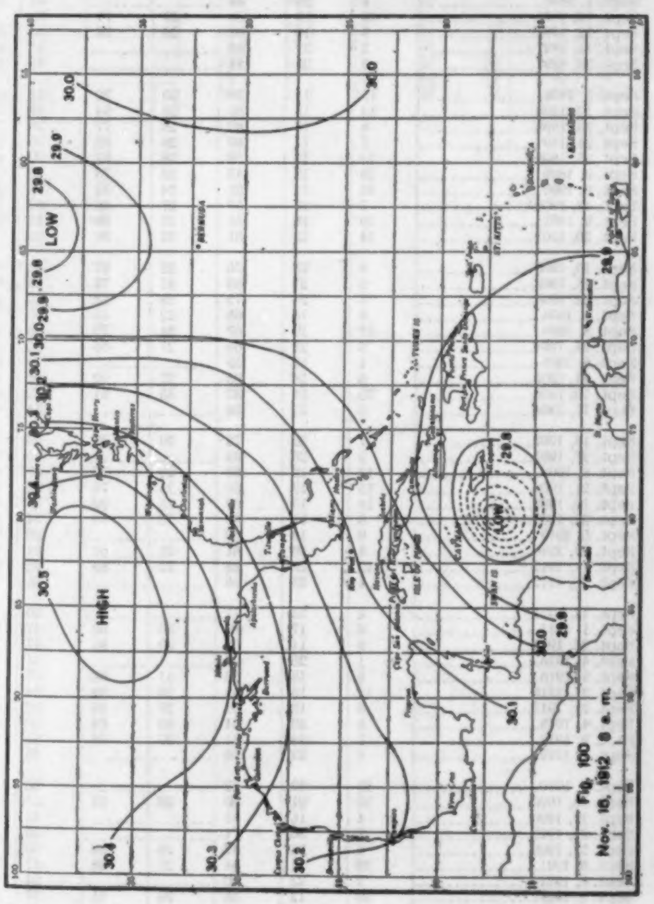


Fig. 100 Nov. 16, 1912 8 a. m.

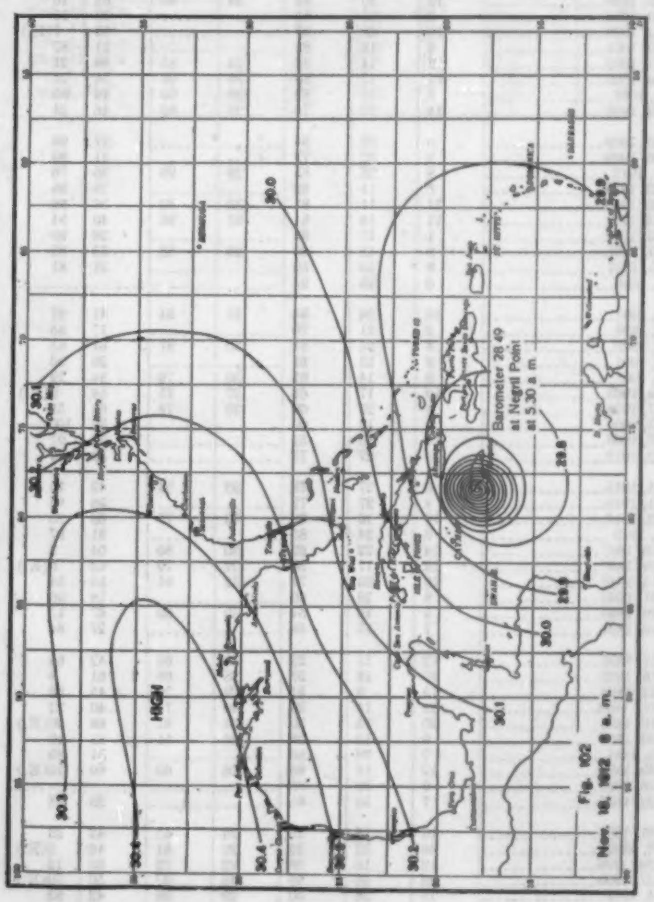


Fig. 102 Nov. 18, 1912 8 a. m.

sugar cane, laying low the cocoanut groves, scattering like chaff the hovels of the poor, reducing to shapeless masses of ruins the better class of dwellings, and sparing nothing in its fury.

Practically one-third of the entire island was thus laid waste. * * * The total loss on the island is estimated at 200 lives, with the destruction of property valued at $1,000,000.

This hurricane was undoubtedly one of the most violent, if not the most violent, that ever struck the Island of Jamaica. The late Maxwell Hall estimated that 18,965 houses were either destroyed or badly damaged. The amount of damage was undoubtedly greatly increased owing to the very slow movement of the hurricane and the consequent continuance of hurricane winds for a great length of time.

During the 18th–20th an anticyclone advanced eastward from the Atlantic States over the ocean to the vicinity of Bermuda, and the progress of the hurricane, which left the north coast between Falmouth and St. Anns Bay early on the 19th, was not only blocked, but the storm rapidly decreased in intensity and filled up between the Island of Jamaica and the Windward Passage. This is one of the very few instances of a hurricane decreasing in intensity and dissipating over the water within the Tropics.

TABLE 2.—*Important data on the life history of all tropical storms of the North Atlantic Ocean, 1887–1923, inclusive*

First observed	Last observed (number days later)	Place first observed		Recurve		Last observed	
		Lat. N.	Long. W.	Lat. N.	Long. W.	Lat. N.	Long. W.
May 16, 1887	11	21	64	32	76	57	12
June 17, 1888	0	28	95	....	....	....	....
June 15, 1889	10	20	85	24	86	68	16
June 10, 1892	6	23	85	....	....	33	75
June 12, 1893	18	20	95	....	....	63	7(E.)
June 10, 1901	4	18	83	....	....	31	87
June 11, 1902	12	14	82	24	85	60	21
June 19, 1902	14	17	85	30	96	54	21
June 8, 1906	8	18	82	38	90	44	80
June 12, 1906	14	22	76	23	82	46	24
June 25, 1909	5	25	84	....	....	27	98
June 26, 1909	5	22	73	....	....	31	89
June 7, 1912	8	23	85	28	93	36	76
June 22, 1913	6	11	82	....	....	28	98
June 29, 1916	11	11	81	33	89	36	86
June 15, 1921	11	14	81	31	96	40	94
June 13, 1922	3	17	87	....	....	26	99
July 20, 1887	8	13	60	25	88	33	85
July 30, 1887	8	10	52	....	....	21	81
July 5, 1888	0	28	95	....	....	....	....
July 3, 1891	10	24	94	31	94	41	27
July 4, 1893	2	11	79	....	....	17	86
July 4, 1896	8	21	81	30	87	61	65
July 2, 1901	8	13	61	....	....	29	96
July 5, 1901	8	14	61	30	76	34	79
July 19, 1903	10	17	61	27	75	54	9(E.)
July 27, 1908	8	22	69	29	79	63	51
July 13, 1909	9	12	60	....	....	30	100
July 27, 1909	14	10	52	....	....	23	97
July 12, 1912	5	27	73	....	....	32	89
July 31, 1915	5	27	78	32	83	42	70
July 11, 1916	4	27	72	....	....	36	83
July 12, 1916	13	16	62	33	75	66	20
July 2, 1919	2	24	85	....	....	31	87
Aug. 16, 1887	14	22	63	30	80	64	2
Aug. 19, 1887	13	17	58	29	79	63	6(E.)
Aug. 14, 1888	10	23	71	32	91	54	54
Aug. 31, 1888	8	19	60	....	....	18	96
Aug. 26, 1890	9	16	54	30	69	67	12
Aug. 18, 1891	7	13	58	....	....	27	84
Aug. 17, 1891	12	13	25	38	65	42	64
Aug. 16, 1892	10	18	57	28	68	61	8
Aug. 13, 1893	13	9	51	29	76	45	36
Aug. 15, 1893	18	14	38	40	74	40	22
Aug. 18, 1893	20	15	30	34	81	66	20(E.)
Aug. 20, 1893	9	12	28	26	41	41	19
Aug. 6, 1894	2	28	88	....	....	31	89
Aug. 30, 1894	12	14	38	26	60	69	10(E.)
Aug. 16, 1895	0	30	88	....	....	....	....
Aug. 22, 1895	7	13	61	....	....	25	98
Aug. 31, 1897	10	14	25	26	41	42	23
Aug. 3, 1899	36	12	36	29	81	46	2(E.)
Aug. 29, 1899	12	16	58	22	72	65	13
Aug. 27, 1900	26	16	46	38	97	50	70(E.)
Aug. 4, 1901	14	26	50	29	90	42	83
Aug. 30, 1901	14	14	38	32	59	70	12
Aug. 7, 1903	8	13	52	....	....	23	100

TABLE 2.—*Important data on the life history of all tropical storms of the North Atlantic Ocean, 1887–1923, inclusive*—Continued

First observed	Last observed (number days later)	Place first observed		Recurve		Last observed	
		Lat. N.	Long. W.	Lat. N.	Long. W.	Lat. N.	Long. W.
Aug. 25, 1906	19	14	29	27	75	65	25
Aug. 21, 1909	6	16	60	....	....	27	99
Aug. 27, 1909	4	20	67	29	82	29	82
Aug. 23, 1910	8	15	56	....	....	26	100
Aug. 9, 1911	5	25	82	....	....	36	92
Aug. 24, 1911	7	27	69	35	83	40	73
Aug. 30, 1913	5	26	72	....	....	35	83
Aug. 5, 1915	19	15	26	32	96	53	65
Aug. 28, 1915	16	24	50	31	67	55	38
Aug. 12, 1916	7	14	55	....	....	31	103
Aug. 22, 1916	11	13	27	....	....	14	89
Aug. 22, 1916	2	13	62	25	80	27	80
Aug. 31, 1917	6	18	52	26	64	52	44
Aug. 1, 1918	5	12	61	....	....	32	94
Aug. 21, 1918	4	12	59	....	....	16	90
Aug. 29, 1923	13	19	60	28	68	55	56
Sept. 1, 1887	6	29	55	33	58	67	10(E.)
Sept. 11, 1887	10	13	57	....	....	26	99
Sept. 15, 1887	3	28	55	35	55	52	43
Sept. 7, 1888	10	26	77	31	83	69	23(E.)
Sept 23, 1888	4	24	81	....	....	48	65
Sept. 1, 1889	12	12	57	....	....	36	76
Sept. 2, 1889	9	16	45	27	58	40	25
Sept. 12, 1889	7	15	27	39	50	43	49
Sept. 12, 1889	14	16	61	24	94	49	63
Sept. 29, 1889	7	11	52	28	67	41	57
Sept. 2, 1891	9	19	59	33	72	67	27
Sept. 16, 1891	17	20	48	33	64	66	11(E.)
Sept. 29, 1891	11	21	55	39	68	67	13
Sept. 4, 1892	13	12	41	29	55	43	12
Sept. 9, 1892	8	24	95	....	....	60	52
Sept. 12, 1892	11	14	18	32	51	37	45
Sept. 25, 1892	2	19	92	....	....	24	98
Sept. 6, 1893	4	24	93	26	93	34	89
Sept. 25, 1893	22	11	26	33	75	68	40
Sept. 27, 1893	7	16	82	27	91	33	74
Sept. 18, 1894	12	12	52	27	82	39	73
Sept. 28, 1895	17	20	87	22	90	46	19
Sept. 3, 1896	8	20	83	....	....	45	70
Sept. 19, 1896	10	19	63	27	74	70	9(E.)
Sept. 22, 1896	9	16	63	25	86	50	62
Sept. 11, 1897	2	27	85	....	....	31	97
Sept. 20, 1897	5	24	84	....	....	54	52
Sept. 5, 1898	15	11	28	30	70	52	55
Sept. 12, 1898	13	13	80	24	94	40	55
Sept. 20, 1898	8	16	60	26	77	28	74
Sept. 21, 1898	7	11	80	28	95	30	94
Sept. 25, 1898	12	17	59	38	87	50	45
Sept. 3, 1899	18	13	43	26	70	60	10(E.)
Sept. 9, 1900	16	12	25	24	33	68	20(E.)
Sept. 13, 1900	7	19	57	27	66	67	22
Sept. 9, 1901	10	18	51	27	89	42	65
Sept. 20, 1901	14	12	81	23	86	66	1
Sept. 10, 1903	4	25	76	32	87	33	82
Sept. 13, 1903	6	27	63	43	78	60	62
Sept. 22, 1903	5	24	72	29	73	52	25
Sept. 3, 1904	8	16	68	22	83	35	73
Sept. 8, 1904	13	19	57	34	79	68	27
Sept. 24, 1904	6	21	64	27	66	34	52
Sept. 6, 1905	1	13	59	....	....	14	64
Sept. 24, 1905	6	18	85	27	92	34	92
Sept. 10, 1906	20	14	32	35	91	52	60
Sept. 11, 1906	6	22	54	....	....	34	82
Sept. 16, 1907	7	22	73	29	89	39	77
Sept. 27, 1907	2	23	93	....	....	35	76
Sept. 8, 1908	12	12	60	24	77	57	40
Sept. 21, 1908	15	12	50	25	78	33	62
Sept. 10, 1909	14	15	62	35	92	58	67
Sept. 22, 1909	8	11	80	22	84	34	64
Sept. 5, 1910	9	16	60	....	....	26	97
Sept. 23, 1910	8	26	61	33	64	64	21
Sept. 11, 1912	12	28	85	32	89	33	22
Sept. 21, 1912	4	23	95	....	....	38	75
Sept. 14, 1914	4	23	77	....	....	30	89
Sept. 1, 1915	6	17	80	30	86	47	82
Sept. 22, 1915	9	14	62	30	90	47	75
Sept. 4, 1916	1	25	77	....	....	34	78
Sept. 9, 1916	5	18	59	31	86	33	84
Sept. 21, 1916	15	19	58	26	69	58	17
Sept. 21, 1917	8	16	64	27	89	32	83
Sept. 4, 1918	4	30	64	40	68	52	58
Sept. 9, 1918	7	14	61	27	76	37	60
Sept. 1, 1919	6	32	70	....	....	65	23
Sept. 2, 1919	13	17	62	....	....	30	102
Sept. 10, 1920	10	21	50	28	53	33	17
Sept. 19, 1920	4	16	85	....	....	43	95
Sept. 22, 1920	1	30	74	....	....	35	80
Sept. 27, 1920	4	24	87	26	87	50	71
Sept. 5, 1921	10	21	54	27	68	57	35
Sept. 6, 1921	1	22	96	....	....	24	99
Sept. 8, 1921	10	12	58	26	71	57	36
Sept. 13, 1922	14	10	51	27	68	50	7
Sept. 17, 1922	5	28	82	....	....	35	71

TABLE 2.—*Important data on the life history of all tropical storms of the North Atlantic Ocean, 1887–1923, inclusive*—Continued

First observed	Last observed (number days later)	Place first observed		Recurve		Last observed	
		Lat. N.	Long. W.	Lat. N.	Long. W.	Lat. N.	Long. W.
Sept. 24, 1923	12	21	71	28	76	65	19
Oct. 6, 1887	2	20	85	....	....	20	95
Oct. 9, 1887	2	19	81	....	....	23	87
Oct. 9, 1887	15	19	61	27	90	65	59
Oct. 11, 1887	0	31	42	....	....	31	42
Oct. 16, 1887	3	17	52	25	56	30	53
Oct. 29, 1887	11	25	85	....	....	46	6
Oct. 8, 1888	4	21	94	....	....	41	72
Oct. 5, 1889	6	21	82	....	....	64	55
Oct. 1, 1891	8	17	60	24	81	40	66
Oct. 6, 1891	5	16	83	21	85	33	77
Oct. 8, 1891	16	24	58	34	76	67	11(E.)
Oct. 12, 1891	10	11	62	25	66	44	10
Oct. 6, 1892	9	11	60	....	....	21	98
Oct. 13, 1892	17	30	70	....	....	55	2
Oct. 21, 1892	11	23	93	....	....	51	15
Oct. 20, 1893	3	23	87	....	....	40	78
Oct. 1, 1894	11	13	80	27	88	57	64
Oct. 11, 1894	8	11	59	23	68	53	51
Oct. 21, 1894	17	30	63	26	75	65	9(E.)
Oct. 2, 1895	5	18	85	25	97	33	93
Oct. 5, 1895	21	12	24	22	83	34	39
Oct. 13, 1895	3	20	93	....	....	30	72
Oct. 7, 1896	9	22	92	....	....	56	48
Oct. 26, 1896	14	8	45	16	56	36	35
Oct. 10, 1897	16	12	61	23	87	60	28
Oct. 23, 1897	15	25	77	....	....	66	21
Oct. 2, 1898	21	12	59	24	84	69	5
Oct. 27, 1898	8	17	63	....	....	17	93
Oct. 2, 1899	7	20	85	26	86	52	54
Oct. 26, 1899	10	13	81	....	....	62	15
Oct. 4, 1900	10	22	63	29	74	60	46
Oct. 9, 1900	6	18	87	23	91	50	66
Oct. 23, 1900	10	24	61	27	74	65	30
Oct. 7, 1901	7	15	53	22	70	46	40
Oct. 16, 1901	4	24	75	....	....	62	58
Oct. 31, 1901	14	22	68	....	....	60	20(E.)
Oct. 7, 1902	11	20	93	....	....	60	15(E.)
Oct. 1, 1903	13	23	60	29	66	62	2
Oct. 7, 1903	19	28	70	35	76	65	19(E.)
Oct. 18, 1903	10	12	53	30	75	57	56
Oct. 10, 1904	6	17	67	24	77	32	55
Oct. 10, 1904	13	11	79	25	83	33	67
Oct. 19, 1904	4	25	47	30	58	30	58
Oct. 28, 1904	10	24	74	26	74	65	21(E.)

TABLE 2.—*Important data on the life history of all tropical storms of the North Atlantic Ocean, 1887–1923, inclusive*—Continued

First observed	Last observed (number days later)	Place first observed		Recurve		Last observed	
		Lat. N.	Long. W.	Lat. N.	Long. W.	Lat. N.	Long. W.
Oct. 29, 1904	13	20	87	25	92	65	10
Oct. 3, 1905	11	13	80	....	....	56	58
Oct. 9, 1906	0	11	82	....	....	12	84
Oct. 11, 1906	11	14	64	21	85	26	82
Oct. 13, 1906	4	33	62	....	....	30	79
Oct. 3, 1907	16	10	52	20	74	55	11
Oct. 17, 1907	4	28	62	31	64	58	40
Oct. 17, 1908	0	12	81	....	....	13	84
Oct. 18, 1908	5	26	52	....	....	34	80
Oct. 25, 1908	10	20	82	23	86	60	60
Oct. 6, 1909	12	11	80	21	83	53	5
Oct. 11, 1910	12	13	81	23	85	30	58
Oct. 2, 1912	2	26	92	....	....	29	83
Oct. 4, 1912	5	29	77	32	77	32	71
Oct. 11, 1912	6	17	82	....	....	28	96
Oct. 3, 1913	6	39	68	....	....	34	81
Oct. 27, 1913	2	17	86	....	....	21	85
Oct. 24, 1914	3	18	86	....	....	31	70
Oct. 3, 1916	2	30	76	....	....	31	82
Oct. 6, 1916	11	12	58	21	65	59	30
Oct. 10, 1916	12	17	79	22	90	53	58
Oct. 21, 1921	9	14	81	24	86	39	41
Oct. 12, 1922	5	17	82	31	87	31	87
Oct. 14, 1922	7	18	79	....	....	18	93
Oct. 13, 1923	4	13	93	16	95	38	91
Oct. 14, 1923	5	20	64	....	....	42	71
Oct. 22, 1923	5	25	76	42	78	52	52
Nov. 27, 1887	9	26	67	23	75	35	51
Nov. 1, 1888	7	13	61	17	61	39	46
Nov. 17, 1888	15	24	57	31	75	49	36
Nov. 21, 1888	2	29	66	....	....	36	51
Nov. 3, 1891	6	24	73	....	....	65	11
Nov. 5, 1891	12	13	80	16	80	51	13(E.)
Nov. 1, 1902	8	23	63	28	64	41	30
Nov. 11, 1904	4	17	81	26	83	51	48
Nov. 6, 1906	7	16	78	18	76	32	28
Nov. 8, 1909	6	10	81	....	....	20	60
Nov. 22, 1909	3	11	78	....	....	28	65
Nov. 25, 1909	7	11	52	29	65	45	54
Nov. 11, 1912	8	11	80	15	82	19	77
Nov. 11, 1916	5	12	80	20	86	37	63
Nov. 11, 1919	3	22	64	28	67	33	66
Dec. 4, 1887	10	19	54	26	63	59	20
Dec. 7, 1887	5	13	60	....	....	13	84

○